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(54) Title: CYTOKINE-, STRESS-, AND ONCOPROTEIN-ACTIVATED HUMAN PROTEIN KINASE KINASES

(57) Abstract

Disclosed are human mitogen-activated (MAP) kinase kinase isoforms (MKKs). MKKs mediate unique signal transduction pathways that activate human MAP kinases p38 and JNK, which result in activation of other factors, including activating transcription factor-2 (ATF2) and c-Jun. The pathways are activated by a number of factors, including cytokines and environmental stress. Methods are provided for identifying reagents that modulate MKK function or activity and for the use of such reagents in the treatment of MKK-mediated disorders.

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CYTOKINE-, STRESS-, AND ONCOPROTEIN-ACTIVATED HUMAN PROTEIN KINASE KINASES

Background of the Invention

This invention relates to protein kinases.

Mitogen-activated protein (MAP) kinases are important mediators of signal transduction from the cell surface to the nucleus. Multiple MAP kinases have been described in yeast including SMK1, HOG1, NPK1, FUS3, and KSS1. In mammals, the MAP kinases identified are extracellular signal-regulated MAP kinase (ERK), c-Jun amino-terminal kinase (JNK), and p38 kinase (Davis (1994) Trends Biochem. Sci. 19:470). These MAP kinase isoforms are activated by dual phosphorylation on threonine and tyrosine.

Activating Transcription Factor-2 (ATF2), ATFa, and cAMP Response Element Binding Protein (CRE-BPa) are related transcription factors that bind to similar sequences located in the promoters of many genes (Ziff (1990) Trends in Genet. 6:69). The binding of these transcription factors leads to increased transcriptional activity. ATF2 binds to several viral proteins, including the oncoprotein E1a (Liu and Green (1994) Nature 368:520), the hepatitis B virus X protein (Maguire et al. (1991) Science 252:842), and the human T cell leukemia virus 1 tax protein (Wagner and Green (1993) Science 262:395). ATF2 also interacts with the tumor suppressor gene product Rb (Kim et al. (1992) Nature 358:331), the high mobility group protein HMG(I)Y (Du et al. (1993) Cell 74:887), and the transcription factors nuclear NF-κB (Du et al. (1993) Cell 74:887) and c-Jun (Benbrook and Jones (1990) Oncogene 5:295).

Summary of the Invention

We have identified and isolated a new group of human mitogen-activated prot in kinase kinases (MKKs).

The MKK isoforms described herein, MKK3, MKK6, and MKK4 (including MKK4-α, -β, and -γ), have serine, threonine, and tyrosine kinase activity, and specifically phosphorylate the human MAP kinase p38 at Thr^{180} and Tyr^{182}. The MKK4 isoforms also phosphorylate the human MAP kinases JNK (including JNK1 and JNK2) at Thr^{183} and Tyr^{185}.

Accordingly, the invention features a substantially pure human MKK polypeptide having serine, threonine, and tyrosine kinase activity that specifically phosphorylates human p38 MAP kinase. MKK3 has the amino acid sequence of SEQ ID NO:2. The invention further includes MKK6 having the amino acid sequence of SEQ ID NO:4 and having serine, threonine, and tyrosine kinase activity that specifically phosphorylates human p38 MAP kinase.

The invention further features a substantially pure human MKK polypeptide having serine, threonine, and tyrosine kinase activity that specifically phosphorylates human p38 MAP kinase and JNK. MKK4 isoform MKK4-α has the amino acid sequence of SEQ ID NO:6. MKK4 isoform MKK4-β has the amino acid sequence of SEQ ID NO:8. MKK4 isoform MKK4-γ has the amino acid sequence of SEQ ID NO:10.

As used herein, the term "mitogen-activating protein kinase kinase" or "MKK" means a protein kinase which possesses the characteristic activity of phosphorylating and activating a human mitogen-activating protein kinase. Examples of MKKs include MKK3 and MKK6, which specifically phosphorylate and activate p38 MAP kinase at Thr^{180} and Tyr^{182}, and MKK4 isoforms which specifically phosphorylate and activate p38 MAP kinase at Thr^{180} and Tyr^{182}, and JNK at Thr^{183} and Tyr^{185}.

The invention includes the specific p38 MKKs disclosed, as well as closely related MKKs which are

identified and isolated by the use of probes or antib dies prepared from the polynucleotide and amino acid sequences disclosed for the MKKs of the invention. This can be done using standard techniques, e.g., by screening a genomic, cDNA, or combinatorial chemical library with a probe having all or a part of the nucleic acid sequences of the disclosed MKKs. The invention further includes synthetic polynucleotides having all or part of the amino acid sequence of the MKKs herein described.

The term "polypeptide" means any chain of amino acids, regardless of length or post-translational modification (e.g., glycosylation or phosphorylation), and includes natural proteins as well as synthetic or recombinant polypeptides and peptides.

The term "substantially pure," when referring to a polypeptide, means a polypeptide that is at least 60%, by weight, free from the proteins and naturally-occurring organic molecules with which it is naturally associated. A substantially pure human MKK polypeptide is at least 75%, more preferably at least 90%, and most preferably at least 99%, by weight, human MKK polypeptide. A substantially pure human MKK can be obtained, for example, by extraction from a natural source; by expression of a recombinant nucleic acid encoding a human MKK polypeptide, or by chemically synthesizing the protein. Purity can be measured by any appropriate method, e.g., column chromatography, polyacrylamide gel electrophoresis, or HPLC analysis.

In one aspect, the invention features isolated and purified polynucleotides which encode the MKKs of the invention. In one embodiment, the polynucleotide is the nucleotide sequence of SEQ ID NO:1. In other embodiments, the polynucleotide is the nucleotide

sequence of SEQ ID NO:3, SEQ ID NO:5, SEQ ID NO:7, or SEQ ID NO:9, respectively.

As used herein, "polynucleotide" refers to a nucleic acid sequence of deoxyribonucleotides or ribonucleotides in the form of a separate fragment or a component of a larger construct. DNA encoding portions or all of the polypeptides of the invention can be assembled from cDNA fragments or from oligonucleotides that provide a synthetic gene which can be expressed in a recombinant transcriptional unit. Polynucleotide sequences of the invention include DNA, RNA, and cDNA sequences, and can be derived from natural sources or synthetic sequences synthesized by methods known to the art.

As used herein, an "isolated" polynucleotide is a polynucleotide that is not immediately contiguous (i.e., covalently linked) with either of the coding sequences with which it is immediately contiguous (i.e., one at the 5′ end and one at the 3′ end) in the naturally-occurring genome of the organism from which the polynucleotide is derived. The term therefore includes, for example, a recombinant polynucleotide which is incorporated into a vector, into an autonomously replicating plasmid or virus, or into the genomic DNA of a prokaryote or eukaryote, or which exists as a separate molecule independent of other sequences. It also includes a recombinant DNA which is part of a hybrid gene encoding additional polypeptide sequences.

The isolated and purified polynucleotide sequences of the invention also include polynucleotide sequences that hybridize under stringent conditions to the polynucleotide sequences specified herein. The term "stringent conditions" means hybridization conditions that guarantee specificity between hybridizing polynucleotide sequences, such as those d scribed herein,

or more stringent conditions. One skilled in the art can select posthybridization washing conditions, including temperature and salt concentrations, which reduce the number of nonspecific hybridizations such that only highly complementary sequences are identified (Sambrook et al. (1989) in Molecular Cloning, 2d ed.; Cold Spring Harbor Laboratory Press, Cold Spring Harbor, NY).

The isolated and purified polynucleotide sequences of the invention also include sequences complementary to the polynucleotide encoding MKK (antisense sequences). Antisense nucleic acids are DNA or RNA molecules that are complementary to at least a portion of a specific mRNA molecule (Weintraub (1990) Scientific American 262:40). The invention includes all antisense polynucleotides capable of inhibiting production of MKK polypeptides. In the cell, the antisense nucleic acids hybridize to the corresponding mRNA, forming a double-stranded molecule. Antisense oligomers of about 15 nucleotides are preferred, since they are easily synthesized and introduced into a target MKK-producing cell. The use of antisense methods to inhibit the translation of genes is known in the art, and is described, e.g., in Marcus-Sakura Anal. Biochem., 172:289 (1988).

In addition, ribozyme nucleotide sequences for MKK are included in the invention. Ribozymes are RNA molecules possessing the ability to specifically cleave other single-stranded RNA in a manner analogous to DNA restriction endonucleases. Through the modification of nucleotide sequences encoding these RNAs, molecules can be engineered to recognize specific nucleotide sequences in an RNA molecule and cleave it (Cech (1988) J. Amer. Med. Assn. 260:3030). A major advantage of this approach is that, because they are sequence-specific, only mRNAs with particular sequences are inactivated.

There are two basic types of ribozymes namely, *tetrahymena*-type (Hasselhoff (1988) Nature 334:585) and "hammerhead"-type. *Tetrahymena*-type ribozymes recognize sequences which are four bases in length, while "hammerhead"-type ribozymes recognize base sequences 11-18 bases in length. The longer the sequence, the greater the likelihood that the sequence will occur exclusively in the target mRNA species. Consequently, hammerhead-type ribozymes are preferable to *tetrahymena*-type ribozymes for inactivating a specific mRNA species, and 18-base recognition sequences are preferable to shorter recognition sequences.

The MKK polypeptides can also be used to produce antibodies that are immunoreactive or bind epitopes of the MKK polypeptides. Accordingly, one aspect of the invention features antibodies to the MKK polypeptides of the invention. The antibodies of the invention include polyclonal antibodies which consist of pooled monoclonal antibodies with different epitopic specificities, as well as distinct monoclonal antibody preparations. Monoclonal antibodies are made from antigen-containing fragments of the MKK polypeptide by methods known in the art (See, for example, Kohler et al. (1975) Nature 256:495).

The term "antibody" as used herein includes intact molecules as well as fragments thereof, such as Fa, $F(ab')_2$, and Fv, which are capable of binding the epitopic determinant. Antibodies that bind MKK polypeptides can be prepared using intact polypeptides or fragments containing small peptides of interest as the immunizing antigen. The polypeptide or peptide used to immunize an animal can be derived from translated cDNA or chemically synthesized, and can be conjugated to a carrier protein, if desired. Commonly used carriers that are chemically coupled to peptides include bovine serum albumin and thyroglobulin. The coupled peptide is then

used to immunize the animal (e.g., a mouse, a rat, or a rabbit).

The invention also features methods of identifying subjects at risk for MKK-mediated disorders by measuring activation of the MKK signal transduction pathway. Activation of the MKK signal transduction pathway can be determined by measuring MKK synthesis; activation of MKK isoforms; activation of MKK substrates p38 or JNK isoforms; or activation of p38 and JNK substrates such as ATF2, ATFa, CRE-BPa, and c-Jun. The term "JNK" or "JNK isoforms" includes both JNK1 and JNK2. The term "MKK substrate" as used herein include MKK substrates, as well as MKK substrate substrates, e.g., p38, JNK, ATF2, and c-Jun.

In one embodiment, activation of the MKK signal transduction pathway is determined by measuring activation of the MKK signal transduction pathway substrates p38, JNK isoforms, ATF2, or c-Jun. MKK activity is measured by the rate of substrate phosphorylation as determined by quantitation of the rate of $[^{32}]P$ incorporation. The specificity of MKK substrate phosphorylation can be tested by measuring p38 and JNK activation, or by employing mutated p38 and JNK molecules that lack the sites of MKK phosphorylations. Altered phosphorylation of the substrate relative to control values indicates alteration of the MKK signal transduction pathway, and increased risk in a subject of an MKK-mediated disorder. MKK activation of p38 and JNK can be detected in a coupled assay with the MKK signal transduction substrate ATF2, or related compounds such as ATFa and CRE-BPa. Activation can also be detected with the substrate c-Jun. When ATF2 is included in the assay, it is present as an intact protein or as a fragment of the intact protein, e.g., the activation domain (residues 1-109, or a portion thereof). ATF2 is incubated with a

test sample in which MKK activity is to be measured and [γ-^{32}P]ATP, und r conditions sufficient to allow the phosphorylation of ATF2. ATF2 is then isolated and the amount of phosphorylation quantitated. In a specific embodiment, ATF2 is isolated by immunoprecipitation, resolved by SDS-PAGE, and detected by autoradiography.

In another embodiment, activation of the MKK signal transduction pathway is determined by measuring the level of MKK expression in a test sample. In a specific embodiment, the level of MKK expression is measured by Western blot analysis. The proteins present in a sample are fractionated by gel electrophoresis, transferred to a membrane, and probed with labeled antibodies to MKK. In another specific embodiment, the level of MKK expression is measured by Northern blot analysis. Polyadenylated [poly(A)$^+$] mRNA is isolated from a test sample. The mRNA is fractionated by electrophoresis and transferred to a membrane. The membrane is probed with labeled MKK cDNA. In another embodiment, MKK expression is measured by quantitative PCR applied to expressed mRNA.

The MKKs of the invention are useful to screen reagents that modulate MKK activity. MKKs are activated by phosphorylation. Accordingly, in one aspect, the invention features methods for identifying a reagent which modulates MKK activity, by incubating MKK with the test reagent and measuring the effect of the test reagent on MKK synthesis, phosphorylation, function, or activity. In one embodiment, the test reagent is incubated with MKK and [^{32}]P-ATP, and the rate of MKK phosphorylation determined, as described above. In another embodiment, the test reagent is incubated with a cell transfected with an MKK polynucleotide expression vector, and the effect of the test reagent on MKK transcription is measured by Northern blot analysis, as described above.

In a further embodiment, the effect of the test reagent on MKK synthesis is measured by Western blot analysis using an antibody to MKK. In still another embodiment, the effect of a reagent on MKK activity is measured by incubating MKK with the test reagent, [^{32}]P-ATP, and a substrate in the MKK signal transduction pathway, including one or more of p38, JNK, and ATF2. The rate of substrate phosphorylation is determined as described above.

The term "modulation of MKK activity" includes inhibitory or stimulatory effects. The invention is particularly useful for screening reagents that inhibit MKK activity. Such reagents are useful for the treatment or prevention of MKK-mediated disorders, for example, inflammation and oxidative damage.

The invention further features a method of treating a MKK-mediated disorder by administering to a subject in need thereof an effective dose of a therapeutic reagent that inhibits the activity of MKK.

By the term "MKK-mediated disorder" is meant a pathological condition resulting, at least in part, from excessive activation of an MKK signal transduction pathway. The MKK signal transduction pathways are activated by several factors, including inflammation and stress. MKK-mediated disorders include, for example, ischemic heart disease, burns due to heat or radiation (UV, X-ray, γ, β, etc.), kidney failure, liver damage due to oxidative stress or alcohol, respiratory distress syndrome, septic shock, rheumatoid arthritis, autoimmune disorders, and other types of inflammatory diseases.

As used herein, the term "therapeutic reagent" means any compound or molecule that achieves the desired effect on an MKK-mediated disorder when administered to a subject in need thereof.

MKK-mediated disorders further include proliferative disorders, particularly disorders that are stress-related. Examples of stress-related MKK-mediated proliferative disorders are psoriasis, acquired immune deficiency syndrome, malignancies of various tissues of the body, including malignancies of the skin, bone marrow, lung, liver, breast, gastrointestinal system, and genito-urinary tract. Preferably, therapeutic reagents inhibit the activity or expression of MKK inhibit cell growth or cause apoptosis.

A therapeutic reagent that "inhibits MKK activity" interferes with a MKK-mediated signal transduction pathway. For example, a therapeutic reagent can alter the protein kinase activity of MKK, decrease the level of MKK transcription or translation, e.g., an antisense polynucleotide able to bind MKK mRNA, or suppress MKK phosphorylation of p38, JNK, or ATF2, thus disrupting the MKK-mediated signal transduction pathway. Examples of such reagents include antibodies that bind specifically to MKK polypeptides, and fragments of MKK polypeptides that competitively inhibit MKK polypeptide activity.

A therapeutic reagent that "enhances MKK activity" supplements a MKK-mediated signal transduction pathway. Examples of such reagents include the MKK polypeptides themselves, which can be administered in instances where the MKK-mediated disorder is caused by underexpression of the MKK polypeptide. In addition, portions of DNA encoding an MKK polypeptide can be introduced into cells that underexpress an MKK polypeptide.

A "therapeutically effective amount" is an amount of a reagent sufficient to decrease or prevent the symptoms associated with the MKK-mediated disorder.

Therapeutic reagents for treatment of MKK-mediated disorders identified by the method of the invention are administered to a subject in a number of ways known to

the art, including parenterally by injection, infusion, sustained-release injection or implant, intravenously, intraperitoneally, intramuscularly, subcutaneously, or transdermally. Epidermal disorders and disorders of the epithelial tissues are treated by topical application of the reagent. The reagent is mixed with other compounds to improve stability and efficiency of delivery (e.g., liposomes, preservatives, or dimethyl sulfoxide (DMSO)). Polynucleotide sequences, including antisense sequences, can be therapeutically administered by techniques known to the art resulting in introduction into the cells of a subject suffering from the MKK-mediated disorder. These methods include the use of viral vectors (e.g., retrovirus, adenovirus, vaccinia virus, or herpes virus), colloid dispersions, and liposomes.

The materials of the invention are ideally suited for the preparation of a kit for the detection of the level or activity of MKK. Accordingly, the invention features a kit comprising an antibody that binds MKK, or a nucleic acid probe that hybridizes to a MKK polynucleotide, and suitable buffers. The probe or monoclonal antibody can be labeled to detect binding to a MKK polynucleotide or protein. In a preferred embodiment, the kit features a labeled antibody to MKK.

Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of the present invention, the preferred methods and materials are described below. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

Other features and advantages of the invention will be apparent from the detailed description, and from the claims.

Detailed Description

The drawings will first be described.

Drawings

Fig. 1 is a comparison of the amino acid sequences of MKK3 (SEQ ID NO:2), MKK4-α (SEQ ID NO:6), the human MAP kinase kinases MEK1 (SEQ ID NO:11) and MEK2 (SEQ ID NO:12), and the yeast HOG1 MAP kinase kinase PBS2 (SEQ ID NO:13). MKK3 and MKK4 sequences were compared with the PILE-UP program (version 7.2; Wisconsin Genetics Computer Group). The protein sequences are presented in single letter code [A, Ala; C, Cys; D, Asp; E, Glu; F, Phe; G, Gly; H, His; I, Ile; K, Lys; L, Leu; M, Met; N, Asn; P, Pro; Q, Gln; R, Arg; S, Ser; T, Thr; V, Val; W, Trp, and Y, Tyr]. The PBS2 sequence is truncated at both the NH_2- (<) and COOH- (>) termini. Gaps introduced into the sequences to optimize the alignment are illustrated by a dash. Identical residues are indicated by a period. The sites of activating phosphorylation in MEK are indicated by asterisks.

Fig. 2 is a dendrogram showing the relation between members of the human and yeast MAP kinase kinases. The dendrogram was created by the unweighted pair-group method with the use of arithmetic averages (PILE-UP program). The human (hu) MAP kinase kinases MEK1, MEK2, MKK3, and MKK4; the *Saccharomyces cerevisiae* (sc) MAP kinase kinases PBS2, MKK1, and STE7; and the *Saccharomyces pombe* (sp) MAP kinase kinases WIS1 and BYR1 are presented.

Fig. 3 is a schematic representation of the ERK, p38, and JNK signal transduction pathways. MEK1 and MEK2 are activat rs of the ERK subgroup of MAP kinase. MKK3

and MKK4 are activators of the p38 MAP kinase. MKK4 is identified as an activator of both the p38 and JNK subgroups of MAP kinase.

Fig. 4 is a representation of the nucleic acid (SEQ ID NO:1) and amino acid sequences (SEQ ID NO:2) for MKK3.

Fig. 5 is a representation of the nucleic acid (SEQ ID NO:3) and amino acid sequences (SEQ ID NO:4) for MKK6.

Fig. 6 is a representation of the nucleic acid (SEQ ID NO:5) and amino acid sequences (SEQ ID NO:6) for MKK4α.

Fig. 7 is a representation of the nucleic acid (SEQ ID NO:7) and amino acid sequences (SEQ ID NO:8) for MKK4β.

Fig. 8 is a representation of the nucleic acid (SEQ ID NO:9) and amino acid sequences (SEQ ID NO:10) for MKK4γ.

Human Mitogen-Activated Protein Kinase Kinases

The human MAP kinase kinases MKK3 and MKK4 (MKK3/4), and MKK6 described herein mediate the transduction of specific signals from the cell surface to the nucleus along specific pathways. These signal transduction pathways are initiated by factors such as cytokines, UV radiation, osmotic shock, and oxidative stress. Activation of MKK3/4 results in activation of the MAP kinases p38 (MKK3/4) and JNK (MKK4). p38 and JNK in turn activate a group of related transcription factors such as ATF2, ATFa, and CRE-BPa. These transcription factors in turn activate expression of specific genes. For example, ATF2 in known to activate expression of human T cell leukemia virus 1 (Wagner and Green (1993) Science 262:395), transforming growth factor-b2 (Kim et al. (1992) supra), interferon-β (Du et al. (1993) Cell

74:887), and E-selectin (DeLuca et al. (1994) J. Biol. Chem. 269:19193). In addition, ATF2 is implicated in the function of a T cell-specific enhancer (Georgopoulos et al. (1992) Mol. Cell. Biol. 12:747).

The isolation of human MKKs is described in Example 1 and in Dérijard et al. (1995) Science 267:682-685. Distinctive regions of the yeast PBS2 sequence were used to design polymerase chain reaction (PCR) primers. Amplification of human brain mRNA with these primers resulted in the formation of specific products which were cloned into a plasmid vector and sequenced. Two different complementary DNAs (cDNAs) that encoded human protein kinases were identified: one encoding a 36 kD protein (MKK3), and one encoding a 44 kD protein (MKK4). MKK4 includes 3 isoforms that vary slightly at the NH_2-terminal, identified as α, β, and γ. The amino acid sequences of MKK3 (SEQ ID NO:2), MKK4-α (SEQ ID NO:6), MKK4-β (SEQ ID NO:8), and MKK4-γ (SEQ ID NO:10) are shown in Fig. 1. The nucleic acid and amino acid sequences of MKK3 (Fig. 5), MKK6 (Fig. 6), MKK4α (Fig. 7), MKK4β (Fig. 8), and MKK4γ (Fig. 9) are also provided. MKK6 was isolated from a human skeletal muscle library by cross-hybridization with MKK3. Except for differences at the N-terminus, MKK6 is homologous to MKK3. Other human MKK3 and MKK4 isoforms that exist can be identified by the method described in Example 1.

The expression of these human MKK isoforms was examined by Northern (RNA) blot analysis of mRNA isolated from eight adult human tissues (Example 2). Both protein kinases were found to be widely expressed in human tissues, with the highest expression seen in skeletal muscle tissue.

The substrate specificity of MKK3 was investigated in an *in vitro* phosphorylation assay with recombinant epitope-tagged MAP kinases (JNK1, p38, and ERK2) as

substrates (Example 3). MKK3 and MKK6 phosphorylated p38, but did not phosphorylate JNK1 or ERK2. Phosphoaminoacid analysis of p38 demonstrated the presence of a phosphothreonine and phosphotyrosine. Mutational analysis of p38 demonstrated that replacement of phosphorylation sites Thr^{180} and Tyr^{182} with Ala and Phe, respectively, blocked p38 phosphorylation. These results establish that MKK3 functions *in vitro* as a p38 MAP kinase kinase. The substrate specificity of MKK6 is similar to that of MKK3, but the specific activity of MKK6 is approximately 300-fold greater than that of MKK3.

Studies of the *in vitro* substrate specificity of MKK4 are described in Example 4. MKK4 incubated with [γ-^{32}P]ATP, and JNK1, p38, or ERK2 was found to phosphorylate both p38 and JNK1. MKK4 activation of JNK and p38 was also studied by incubating MKK4 with wild-type or mutated JNK1 or p38. The p38 substrate ATF2 was included in each assay. MKK4 was found to exhibit less autophosphorylation than MKK3. MKK4 was also found to be a substrate for activated MAP kinase. Unlike MKK3 and MKK6, MKK4 was also found to activate JNK1. MKK4 incubated with wild-type JNK1, but not mutated JNK1, resulted in increased phosphorylation of ATF2. These results establish that MKK4 is a p38 MAP kinase kinase that also phosphorylates the JNK subgroup of MAP kinases.

In vivo activation of p38 by UV-stimulated MKK3 is described in Example 5. Cells expressing MKK3 were exposed in the presence or absence of UV radiation. MKK3 was isolated by immunoprecipitation and used for protein kinase assays with the substrates p38 or JNK. ATF2 was included in some assays as a substrate for p38 and JNK. MKK3 from non-activated cultured COS cells caused a small amount of phosphorylation of p38 MAP kinase, resulting from basal activity of MKK3. MKK3 from UV-irradiated cells caused increased phosphorylation of p38 MAP kinase,

but not of JNK1. An increase in p38 activity was also detect d in assays in which ATF2 was included as a substrate. These results establish that MKK3 is activated by UV radiation.

The effect of expression of MKK3 and MKK4 on p38 activity was examined in COS-1 cells (Example 6). Cells were transfected with a vector encoding p38 and a MEK1, MKK3, or MKK4. Some of the cells were also exposed to EGF or UV radiation. p38 was isolated by immunoprecipitation and assayed for activity with [γ-^{32}P]ATP and ATF2. The expression of the ERK activator MEK1 did not alter p38 phosphorylation of ATF2. In contrast, expression of MKK3 or MKK4 caused increased activity of p38 MAP kinase. The activation of p38 caused by MKK3 and MKK4 was similar to that observed in UV-irradiated cells, and was much greater than that detected in EGF-treated cells. These *in vitro* results provide evidence that MKK3 and MKK4 activate p38 *in vivo*.

A series of experiments was conducted to examine the potential regulation of ATF2 by JNK1. These experiments are described in Gupta et al. (1995) Science 267:389-393. The effect of UV radiation on ATF2 phosphorylation was investigated in COS-1 cells transfected with and without epitope-tagged JNK1 (Example 7). Cells were exposed to UV radiation, and JNK1 and JNK2 visualized by in-gel protein kinase assay with the substrate ATF2. JNK1 and JNK2 were detected in transfected and non-transfected cells exposed to UV radiation; however, JNK1 levels were higher in the transfected cells. These results demonstrate that ATF2 is a substrate for the JNK1 and JNK2 protein kinases, and that these protein kinases are activated in cells exposed to UV light.

The site of JNK1 phosphorylation of ATF2 was examined by deletion analysis (Example 8). Progressive

NH_2-terminal domain deletion GST-ATF2 fusion proteins were generated, and phosphorylation by JNK1 isolated from UV-irradiated cells was examined. The results showed that JNK1 requires the presence of ATF2 residues 1-60 for phosphorylation of the NH_2-terminal domain of ATF2.

The ATF2 residues required for binding of JNK1 were similarly examined. JNK1 was incubated with immobilized ATF2, unbound JNK1 was removed by extensive washing, and bound JNK1 was detected by incubation with [γ-^{32}P]ATP. Results indicate that residues 20 to 60 of ATF2 are required for binding and phosphorylation by JNK1. A similar binding interaction between ATF2 and the 55 kD JNK2 protein kinase has also been observed.

Phosphorylation by JNK1 was shown to reduce the electrophoretic mobility of ATF2 (Example 9). Phosphoamino acid analysis of the full-length ATF2 molecule (residues 1-505) demonstrated that JNK phosphorylated both Thr and Ser residues. The major sites of Thr and Ser phosphorylation were located in the NH_2 and COOH terminal domains, respectively. The NH_2-terminal sites of phosphorylation were identified as Thr^{69} and Thr^{71} by phosphopeptide mapping and mutational analysis. These sites of Thr phosphorylation are located in a region of ATF2 that is distinct from the sub-domain required for JNK binding (residues 20 to 60).

The reduced electrophoretic mobility seen with phosphorylation of ATF2 was investigated further (Example 10). JNK1 was activated in CHO cells expressing JNK1 by treatment with UV radiation, pro-inflammatory cytokine interleukin-1 (IL-1), or serum. A decreased electrophoretic mobility of JNK1-activated ATF2 was observed in cells treated with UV radiation and IL-1. Smaller effects were seen after treatment of cells with serum. These results indicate that ATF2 is an *in vivo* substrate for JNK1.

The effect of UV radiation on the properties of wild-type ($Thr^{69,71}$) and phosphorylation-defective ($Ala^{69,71}$) ATF2 molecules was investigated (Example 11). Exposure to UV caused a decrease in the electrophoretic mobility of both endogenous and over-expressed wild-type ATF2. This change in electrophoretic mobility was associated with increased ATF2 phosphorylation. Both the electrophoretic mobility shift and increased phosphorylation were blocked by the replacement of Thr^{69} and Thr^{71} with Ala in ATF2. This mutation also blocked the phosphorylation of ATF2 on Thr residues *in vivo*.

Transcriptional activities of fusion proteins consisting of the GAL4 DNA binding domain and wild-type or mutant ATF2 were examined (Example 12). Point mutations at Thr^{69} and/or Thr^{71} of ATF2 significantly decreased the transcriptional activity of ATF2 relative to the wild-type molecule, indicating the physiological relevance of phosphorylation at these sites for activity.

The binding of JNK1 to the NH_2-terminal activation domain of ATF2 (described in Example 8) suggested that a catalytically inactive JNK1 molecule could function as a dominant inhibitor of the wild-type JNK1 molecule. This hypothesis was investigated by examining the effect of a catalytically inactive JNK1 molecule on ATF2 function (Example 13). A catalytically-inactive JNK1 mutant was constructed by replacing the sites of activating Thr^{183} and Tyr^{185} phosphorylation with Ala and Phe, respectively (Ala^{183},Phe^{185}, termed "dominant-negative"). Expression of wild-type JNK1 caused a small increase in serum-stimulated ATF2 transcriptional activity. In contrast, dominant-negative JNK1 inhibited both control and serum-stimulated ATF2 activity. This inhibitory effect results from the non-productive binding of the JNK1 mutant to the ATF2 activation domain, effectively blocking ATF2 phosphorylati n.

The tumor suppressor gene product Rb binds to ATF2 and increases ATF2-stimulated gene expression (Kim et al. (1992) Nature 358:331). Similarly, the adenovirus oncoprotein E1A associates with the DNA binding domain of ATF2 and increases ATF2-stimulated gene expression by a mechanism that requires the NH_2-terminal activation domain of ATF2 (Liu and Green (1994) Nature 368:520). ATF2 transcriptional activity was investigated with the luciferase reporter gene system in control, Rb-treated, and E1A-treated cells expressing wild-type or mutant ATF2 molecules (Example 14). Rb and E1A were found to increase ATF2-stimulated gene expression of both wild-type and mutant ATF2. However, mutant ATF2 caused a lower level of reporter gene expression than did wild-type ATF2. Together, these results indicate a requirement for ATF2 phosphorylation (on Thr^{69} and Thr^{71}) plus either Rb or E1A for maximal transcriptional activity. Thus, Rb and E1A act in concert with ATF2 phosphorylation to control transcriptional activity.

A series of experiments were conducted to examine the action of p38 activation and to establish the relationship of the p38 MAP kinase pathway to the ERK and JNK signal transduction pathways (Raingeaud et al. (1995) J. Biol. Chem. 270:7420). Initially, the substrate specificity of p38 was investigated by incubating p38 with proteins that have been demonstrated to be substrates for the ERK and/or JNK groups of MAP kinases (Example 15). We examined the phosphorylation of MBP (Erickson et al. (1990) J. Biol. Chem. 265:19728), EGF-R (Northwood et al. (1991) J. Biol. Chem. 266:15266), cytoplasmic phospholipase A_2 ($cPLA_2$) (Lin et al. (1993) Cell 72:269), c-Myc (Alvarez et al. (1991) J. Biol. Chem. 266:15277), IκB, c-Jun, and wild-type ($Thr^{69,71}$) or mutated ($Ala^{69,71}$) ATF2. p38 phosphorylated MBP and EGF-R, and to a lesser extent IκB, but not the other ERK

substrates, demonstrating that the substrate specificity of p38 differs from both the ERK and JNK groups of MAP kinases. Wild-type ATF2, but not mutated ATF2 ($Ala^{69,71}$), was found to be an excellent p38 substrate.

The phosphorylation of ATF2 by p38 was associated with an electrophoretic mobility shift of ATF2 during polyacrylamide gel electrophoresis. We tested the hypothesis that p38 phosphorylates ATF2 at the same sites as JNK1 by replacing Thr^{69} and Thr^{71} with Ala ($Ala^{69,71}$). It was found that p38 did not phosphorylate mutated ATF2, which demonstrates that p38 phosphorylates ATF2 within the NH_2-terminal activation domain on Thr^{69} and Thr^{71}.

A comparison of the binding of JNK and p38 to ATF2 was conducted by incubating extracts of cells expressing JNK1 or p38 with epitope alone (GST) or GST-ATF2 (residues 1-109 containing the activation domain) (Example 16). Bound protein kinases were detected by Western blot analysis. The results demonstrate that both p38 and JNK bind to the ATF2 activation domain.

EGF and phorbol ester are potent activators of the ERK signal transduction pathway (Egan and Weinberg (1993) Nature 365:781), causing maximal activation of the ERK sub-group of MAP kinases. These treatments, however, cause only a small increase in JNK protein kinase activity (Dérijard et al. (1994) supra; Hibi et al. (1993) supra). The effects of EGF or phorbol esters, as well UV radiation, osmotic shock, interleukin-1, tumor necrosis factor, and LPS, on p38 activity were all tested (Example 17). Significantly, EGF and phorbol ester caused only a modest increase in p38 protein kinase activity, whereas environmental stress (UV radiation and osmotic shock) caused a marked increase in the activity of both p38 and JNK. Both p38 and JNK were activated in cells treated with pro-inflammatory cytokines (TNF and IL-1) or endotoxic LPS. Together, these results indicate

that p38, like JNK, is activated by a stress-induced signal transduction pathway.

ERKs and JNKs are activated by dual phosphorylation within the motifs Thr-Glu-Tyr and Thr-Pro-Tyr, respectively. In contrast, p38 contains the related sequence Thr-Gly-Tyr. To test whether this motif is relevant to the activation of p38, the effect of the replacement of Thr-Gly-Tyr with Ala-Gly-Phe was examined (Example 18). The effect of UV radiation on cells expressing wild-type (Thr^{180},Tyr^{182}) or mutant p38 (Ala^{180},Phe^{182}) was studied. Western blot analysis using an anti-phosphotyrosine antibody demonstrated that exposure to UV radiation caused an increase in the Tyr phosphorylation of p38. The increased Tyr phosphorylation was confirmed by phosphoaminoacid analysis of p38 isolated from [γ-^{32}P]phosphate-labeled cells. This analysis also demonstrated that UV radiation caused increased Thr phosphorylation of p38. Significantly, the increased phosphorylation on Thr^{180} and Tyr^{182} was blocked by the Ala^{180}/Phe^{182} mutation. This result demonstrates that UV radiation causes increased activation of p38 by dual phosphorylation.

It has recently been demonstrated that ERK activity is regulated by the mitogen-induced dual specificity phosphatases MKP1 and PAC1 (Ward et al. (1994) Nature 367:651). The activation of p38 by dual phosphorylation (Example 18) raises the possibility that p38 may also be regulated by dual specificity phosphatases. We examined the effect of MKP1 and PAC1 on p38 MAP kinase activation (Example 19). Cells expressing human MKP1 and PAC1 were treated with and without UV radiation, and p38 activity measured. The expression of PAC1 or MKP1 was found to inhibit p38 activity. The inhibitory effect of MKP1 was greater than PAC1. In contrast, cells transfected with a catalytically inactive

mutant phosphatase (mutant PAC1 Cys^{257}/Ser) did not inhibit p38 MAP kinase. These results demonstrate that p38 can be regulated by dual specificity phosphatases PAC1 and MKP1.

The sub-cellular distribution of p38 MAP kinase was examined by indirect immunofluorescence microscopy (Example 20). Epitope-tagged p38 MAP kinase was detected using the M2 monoclonal antibody. Specific staining of cells transfected with epitope-tagged p38 MAP kinase was observed at the cell surface, in the cytoplasm, and in the nucleus. Marked changes in cell surface and nuclear p38 MAP kinase were not observed following UV irradiation, but an increase in the localization of cytoplasmic p38 MAP kinase to the perinuclear region was detected.

A series of experiments were conducted to study the activation of JNK by hyper-osmotic media (Example 21). These experiments were reported by Galcheva-Gargova et al. (1994) Science 265:806. CHO cells expressing epitope-tagged JNK1 were incubated with 0 - 1000 mM sorbitol, and JNK1 activity measured in an immune complex kinase assay with the substrate c-Jun. Increased JNK1 activity was observed in cells incubated 1 hour with 100 mM sorbitol. Increased JNK1 activity was observed within 5 minutes of exposure to 300 mM sorbitol. Maximal activity was observed 15 to 30 minutes after osmotic shock with a progressive decline in JNK1 activity at later times. The activation of JNK by osmotic shock was studied in cells expressing wild-type (Thr^{183}, Tyr^{185}) or mutated (Ala^{183}, Phe^{185}) JNK1. JNK1 activity was measured after incubation for 15 minutes with or without 300 mM sorbitol. Cells expressing wild-type JNK1 showed increased JNK1 activity, while cells expressing mutated JNK1 did not. These results demonstrate that the JNK

signal transduction pathway is activated in cultured mammalian cells exp sed to hyper-osmotic media.

The results of the above-described experiments are illustrated in Fig. 3, which diagrams the ERK, p38, and JNK MAP kinase signal transduction pathways. ERKs are potently activated by treatment of cells with EGF or phorbol esters. In contrast, p38 is only slightly activated under these conditions (Example 15). However, UV radiation, osmotic stress, and inflammatory cytokines cause a marked increase in p38 activity. This difference in the pattern of activation of ERK and p38 suggests that these MAP kinases are regulated by different signal transduction pathways. The molecular basis for the separate identity of these signal transduction pathways is established by the demonstration that the MAP kinase kinases that activate ERK (MEK1 and MEK2) and p38 (MKK3, MKK6, and MKK4) are distinct.

MKK isoforms are useful for screening reagents which modulate MKK activity. Described in the Use section following the examples are methods for identifying reagents capable of inhibiting or activating MKK activity.

The discovery of human MKK isoforms and MKK-mediated signal transduction pathways is clinically significant for the treatment of MKK-mediated disorders. One use of the MKK isoforms is in a method for screening reagents able to inhibit or prevent the activation of the MKK-MAP kinase- ATF2 pathways.

The following examples are meant to illustrate, not limit, the invention.

Example 1. MKK Protein Kinases

The primary sequences of MKK3 and MKK4 were deduced from the sequence of cDNA clones isolated from a human fetal brain library.

The primers TTYTAYGGNGCNTTYTTYATHGA (SEQ ID NO:14) and ATBCTYTCNGGNGCCATKTA (SEQ ID NO:15) were designed based on the sequence of PBS2 (Brewster et al. (1993) Science 259:1760; Maeda et al. (1994) Nature 369:242). The primers were used in a PCR reaction with human brain mRNA as template. Two sequences that encoded fragments of PBS2-related protein kinases were identified. Full-length human cDNA clones were isolated by screening of a human fetal brain library (Dérijard et al. (1994) supra). The cDNA clones were examined by sequencing with an Applied Biosystems model 373A machine. The largest clones obtained for MKK3 (2030 base pairs (bp)) and MKK4 (3576 bp) contained the entire coding region of these protein kinases.

The primary structures of MKK3 (SEQ ID NO:2) and MKK4α (SEQ ID NO:6) are shown in Fig. 1. An in-frame termination codon is located in the 5′ untranslated region of the MKK3 cDNA, but not in the 5′ region of the MKK4 cDNA. The MKK4 protein sequence presented starts at the second in-frame initiation codon.

These sequences were compared to those of the human MAP kinase kinases MEK1 (SEQ ID NO:11) and MEK2 (SEQ ID NO:12) (Zheng and Guan (1993) J. Biol. Chem 268:11435) and of the yeast MAP kinase kinase PBS2 (SEQ ID NO:13) (Boguslawaski and Polazzi (1987) Proc. Natl. Acad. Sci. USA 84:5848) (Fig. 1). The identity and similarity of the kinases with human MKK3 (between subdomains I and XI) were calculated with the BESTFIT program (version 7.2; Wisconsin Genetics Computer Group) (percent of identity to percent of similarity): MEK1, 41%/63%; MEK2, 41%/62%; MKK4α, 52%/73%; and PBS2, 40%/59%). The identity and similarity of the kinases with human MKK4α were calculated to be as follows (percent of identity to percent of similarity): MEK1, 44%/63%; MEK2, 45%/61%; MKK3, 52%/73%; and PBS2, 44%/58%.

The cDNA sequences of MKK3 and MKK4γ have been deposited in GenBank with accession numbers L36719 and L36870, respectively. The MKK4γ cDNA sequence contains both the cDNA sequences of MKK4α and MKK4β, which are generated *in vivo* from alternate splicing sites. One of ordinary skill in the art can readily determine the amino acid sequences of MKK3 and MKK4 isoforms from the deposited cDNA sequences.

Human MKK6 cDNA clones were isolated from a skeletal muscle library by screening with an MKK3 probe at low stingency. Mammalian MKK6 expression vectors were constructed by sub-cloning the MKK6 cDNA in the *Hind*III and *Xba*I sites of pCDNA3 (Invitrogen Inc.). The sequences of all plasmids were confirmed by automated sequencing with an Applied Biosystems model 373A machine.

Example 2. Expression of MKK3 and MKK4 mRNA in Adult Human Tissue

Northern blot analysis was performed with polyadenylated [poly(A)$^+$] mRNA (2 μg) isolated from human heart, brain, placenta, lung, liver, muscle, kidney, and pancreas tissues. The mRNA was fractionated by denaturing agarose gel electrophoresis and was transferred to a nylon membrane. The blot was probed with the MKK3 and MKK4 cDNA labeled by random priming with [α-^{32}P]ATP (deoxyadenosine triphosphate) (Amersham International PLC). MKK3 and MKK4 were expressed in all tissues examined; the highest expression of MKK3 and MKK4 was found in skeletal muscle tissue.

The relation between members of the human and yeast MAP kinase kinase group is presented as a dendrogram (Fig. 2). MKK3/4 form a unique subgroup of human MAP kinase kinases.

Example 3. *In Vitro* Phosphorylation of p38 MAP kinase by MKK3

GST-JNK1, and GST-ERK2 have been described (Dérijard et al. (1994) supra; Gupta et al. (1995) Science 267:389; Wartmann and Davis (1994) J. Biol. Chem. 269:6695). GST-p38 MAP kinase was prepared from the expression vector pGSTag (Dressier et al. (1992) Biotechniques 13:866) and a PCR fragment containing the coding region of the p38 MAP kinase cDNA. GST-MKK3 and MKK4 were prepared with pGEX3X (Pharmacia-LKB Biotechnology) and PCR fragments containing the coding region of the MKK3 and MKK4 cDNAs. The GST fusion proteins were purified by affinity chromatography with the use of GSH-agarose (Smith and Johnson (1988) Gene 67:31). The expression vectors pCMV-Flag-JNK1 and pCMV-MEK1 have been described (Dérijard et al. (1994) supra; Wartmann and Davis (1994) supra). The plasmid pCMV-Flag-p38 MAP kinase was prepared with the expression vector pCMV5 (Andersson et al. (1989) J. Biol. Chem. 264:8222) and the p38 MAP kinase cDNA. The expression vectors for MKK3 and MKK4 were prepared by subcloning of the cDNAs into the polylinker of pCDNA3 (Invitrogen). The Flag epitope (Asp-Tyr-Lys-Asp-Asp-Asp-Asp-Lys (SEQ ID NO:16); Immunex, Seattle, WA) was inserted between codons 1 and 2 of the kinases by insertional overlapping PCR (Ho et al. (1989) Gene 77:51).

Protein kinase assays were performed in kinase buffer (25 mM 4-(2-hydroxyethyl)-1-piperazineethansulfonic acid, pH 7.4, 25 mM β-glycerophosphate, 25 mM $MgCl_2$, 2 mM dithiothreitol, and 0.1 mM orthovanadate). Recombinant GST-MKK3 was incubated with [γ-^{32}P]ATP and buffer, GST-JNK1, GST-p38 MAP kinase, or GST-ERK2. The assays were initiated by the addition of 1 μg of substrate proteins and 50 μM [γ-^{32}P]ATP (10 Ci/mmol) in a final volume of 25 μl. The

reactions were terminated after 30 minutes at 25°C by addition of Laemmli sample buffer. The phosphorylation of the substrate proteins was examined after SDS-polyacrylamide gel electrophoresis (SDS-PAGE) by autoradiography. Phosphoaminoacid analysis was performed by partial acid hydrolysis and thin-layer chromatography (Dérijard et al. (1994) supra; Alvarez et al. (1991) J. Biol. Chem. 266:15277). Autophosphorylation of MKK3 was observed in all groups. MKK3 phosphorylated p38 MAP kinase, but not JNK1 or ERK2.

A similar insertional overlapping PCR procedure was used to replace Thr^{180} and Tyr^{182} of p38, with Ala and Phe, respectively. The sequence of all plasmids was confirmed by automated sequencing on an Applied Biosystems model 373A machine. GST-MKK3 was incubated with [γ-^{32}P]ATP and buffer, wild-type GST-p38 MAP kinase (TGY), or mutated GST-p38 MAP kinase (AGF). The phosphorylated proteins were resolved by SDS-PAGE and detected by autoradiography. Only phosphorylation of wild-type p38 was observed.

MKK6 was similarly tested and shown to phosphorylate p38 MAP kinase on Thr^{180} and Tyr^{182}, but not JNK1 or ERK2. The specific activity of MKK6 was approximately 300-fold greater than that of MKK3.

Example 4. *In Vitro* Phosphorylation and Activation of JNK and p38 MAP Kinase by MKK4

Protein kinase assays were conducted as described in Example 3. Recombinant GST-MKK4 was incubated with [γ-^{32}P]ATP and buffer, GST-JNK1, GST-p38 MAP kinase, or GST-ERK2. JNK1 and p38 were phosphorylated, as was MKK4 incubated with JNK1 and p38.

GST-MKK4 was incubated with [γ-^{32}P]ATP and buffer, wild-type JNK1 (Thr^{183}, Tyr^{185}), or mutated GST-JNK1 (Ala^{183}, Phe^{185}). The JNK1 substrate ATF2 (Gupta et al.

(1995) supra) was included in each incubation. ATF2 was phosphorylated in the presence of MKK4 and wild-type JNK1. The results establish that MKK4 phosphorylates and activates both p38 and JNK1.

Example 5. Phosphorylation and Activation of p38 MAP Kinase by UV-stimulated MKK3

Epitope-tagged MKK3 was expressed in COS-1 cells maintained in Dulbecco's modified Eagle's medium supplemented with fetal bovine serum (5%)(Gibco-BRL). The cells were transfected with the lipofectamine reagent according to the manufacturer's recommendations (Gibco-BRL) and treated with UV radiation or EGF as described (Dérijard et al. (1994) supra).

The cells were exposed in the absence and presence of UV-C (40 J/m^2). The cells were solubilized with lysis buffer (20 mM tris, pH 7.4, 1% Triton X-100, 10% glycerol, 137 mM NaCl, 2 mM EDTA, 25 mM β-glycerophosphate, 1 mM Na orthovanadate, 1 mM phenylmethylsulfonyl fluoride, and leupeptin (10 μg/ml)) and centrifuged at 100,000 x g for 15 minutes at 4°C. MKK3 was isolated by immunoprecipitation. The epitope-tagged protein kinases were incubated for 1 hour at 4°C with the M2 antibody to the Flag epitope (IBI-Kodak) bound to protein G-Sepharose (Pharmacia-LKB Biotechnology). The immunoprecipitates were washed twice with lysis buffer and twice with kinase buffer.

Protein kinase assays were conducted with the substrate GST-p38 MAP kinase or JNK1. ATF2 was included in some assays. Basal levels of MKK3 phosphorylation of p38 MAP kinase were observed. UV-irradiation resulted in increased phosphorylation of p38 MAP kinase, but not of JNK1. The increased p38 MAP kinase activity resulted in increased phosphorylation of ATF2.

Example 6. Activation of p38 MAP Kinase in Cells Expressing MKK3 and MKK4

COS-1 cells were transfected with epitope-tagged p38 MAP kinase, together with an empty expression vector or an expression vector encoding MEK1, MKK3, or MKK4α. Some of the cultures were exposed to UV radiation (40 J/m^2) or treated with 10 nM EGF. p38 MAP kinase was isolated by immunoprecipitation with M2 monoclonal antibody, and the protein kinase activity was measured in the immunecomplex with [γ-^{32}P]ATP and ATF2 as substrates. The product of the phosphorylation reaction was visualized after SDS-PAGE by autoradiography. ATF2 was not phosphorylated in the control MEK1, or EGF-treated groups, but was phosphorylated in the MKK3, MKK4, and UV-irradiated groups. MKK3 and MKK4 phosphorylation of ATF2 was similar to that seen with p38 MAP kinase isolated from UV-irradiated cells.

Example 7. Phosphorylation of ATF2 by JNK1 and JNK2

COS-1 cells were maintained in Dulbecco's modified Eagle's medium supplemented with bovine serum albumin (5%) (Gibco-BRL). Metabolic labeling with [^{32}]P was performed by incubation of cells for 3 hours in phosphate-free modified Eagle's medium (Flow Laboratories Inc.) supplemented with [^{32}P]orthophosphate (2 mCi/ml) (Dupont-NEN). COS-1 cells were transfected without (Mock) and with epitope-tagged JNK1 (JNK1). Plasmid expression vectors encoding the JNK1 cDNA have previously been described (Dérijard et al. (1994) Cell 76:1025). Plasmid DNA was transfected into COS-1 cells by the lipofectamine method (Gibco-BRL). After 48 hours of incubation, some cultures were exposed to 40 J/m^2 UV radiation and incubated for 1 hour at 37°C.

Cells were lysed in 20 mM Tris, pH 7.5, 25 mM β-glycerophosphate, 10% glycerol, 1% Triton X-100, 0.5%

(w/v) deoxycholate, 0.1% (w/v) SDS, 0.137 M NaCl, 2 mM pyr phosphate, 1 mM orthovanadate, 2 mM EDTA, 10 μg/ml leupeptin, 1 mM PMSF. Soluble extracts were prepared by centrifugation in a microfuge for 20 minutes at 4°C. JNK1 immunoprecipitates were also prepared by reaction with a rabbit antiserum prepared with recombinant JNK1 as an antigen.

In-gel protein kinase assays were performed with cell lysates and JNK1 immunoprecipitates after SDS-PAGE by renaturation of protein kinases, polymerization of the substrate (GST-ATF2, residues 1-505) in the gel, and incubation with [γ-^{32}P]ATP (Dérijard et al. (1994) supra). The incorporation of [^{32}P]phosphate was visualized by autoradiography and quantitated with a Phosphorimager and ImageQuant soft-ware (Molecular Dynamics Inc., Sunnyvale, CA). The cell lysates demonstrate the presence of 46 kD and 55 kD protein kinases that phosphorylate ATF2 in extracts prepared from UV-irradiated cells. The 46 kD and 55 kD protein kinases were identified as JNK1 and JNK2, respectively.

Example 8. Binding of JNK1 to ATF2 and Phosphorylation of the NH_2-Terminal Activation Domain

The site of JNK1 phosphorylation of ATF2 was investigated by generation of progressive NH_2-terminal domain deletions of ATF2. Plasmid expression vectors encoding ATF2 (pECE-ATF2) (Liu and Green (1994) and (1990)), have been described. Bacterial expression vectors for GST-ATF2 fusion proteins were constructed by sub-cloning ATF2 cDNA fragments from a polymerase chain reaction (PCR) into pGEX-3X (Pharmacia-LKB Biotechnology Inc.). The sequence of all constructed plasmids was confirmed by automated sequencing with an Applied Biosystems model 373A machine. The GST-ATF2 proteins were purified as described (Smith and Johnson (1988) Gene

67:31), resolved by SDS-PAGE and stained with Coomassie blue. GST-ATF2 fusion proteins contained residues 1-505, 1-349, 350-505, 1-109, 20-109, 40-109, and 60-109.

The phosphorylation of GST-ATF2 fusion proteins by JNK1 isolated from UV-irradiated cells was examined in an immunocomplex kinase assay. Immunecomplex kinase assays were performed with Flag epitope-tagged JNK1 and the monoclonal antibody M2 (IBI-Kodak) as described by Dérijard et al. (1994) supra). Immunecomplex protein kinase assays were also performed with a rabbit antiserum prepared with recombinant JNK1 as an antigen. The cells were solubilized with 20 mM Tris, pH 7.5, 10% glycerol, 1% Triton X-100, 0.137 M NaCl, 25 mM β-glycerophosphate, 2 mM EDTA, 1 mM orthovanadate, 2 mM pyrophosphate, 10 μg/ml leupeptin, and 1 mM PMSF. JNK1 was immunoprecipitated with protein G-Sepharose bound to a rabbit polyclonal antibody to JNK or the M2 monoclonal antibody to the Flag epitope. The beads were washed three times with lysis buffer and once with kinase buffer (20 mM Hepes, pH 7.6, 20 mM $MgCl_2$, 25 mM β-glycerophosphate, 100 μM Na orthovanadate, 2 mM dithiothreitol). The kinase assays were performed at 25°C for 10 minutes with 1 μg of substrate, 20 μM adenosine triphosphate and 10 μCi of [γ-^{32}P]ATP in 30μl of kinase buffer. The reactions were terminated with Laemmli sample buffer and the products were resolved by SDS-PAGE (10% gel). JNK1 phosphorylates GST-ATF2 fusion proteins containing residues 1-505, 1-349, 1-109, 20-109, and 40-109, but not 60-109. These results indicate that the presence of ATF2 residues 1-60 are required for phosphorylation by JNK.

The binding of immobilized GST-ATF2 fusion proteins was examined in a solid-phase kinase assay as described by Hibi et al. (1993) Genes Dev. 7:2135. JNK1 from UV-irradiated cells was incubated with GST-ATF2

fusion proteins bound to GSH-agarose. The agarose beads were washed extensively to remove the unbound JNK1. Phosphorylation of the GST-ATF2 fusion proteins by the bound JNK1 protein kinase was examined by addition of [γ-^{32}P]ATP. JNK1 bound GST-ATF2 fusion proteins containing residues 1-505, 1-349, 1-109, 20-109, and 40-109, indicating that the presence of residues 20-60 were required for binding of JNK1 to ATF2.

Example 9. Phosphorylation of the NH_2-terminal Activation Domain of ATF2 on Thr^{69} and Thr^{71} by JNK1

The effect of UV radiation on the properties of wild-type ($Thr^{69,71}$) and phosphorylation-defective ($Ala^{69,71}$) ATF2 molecules was examined. Mock-transfected and JNK1-transfected COS cells were treated without and with 40 J/m^2 UV radiation. The epitope-tagged JNK1 was isolated by immunoprecipitation with the M2 monoclonal antibody. The phosphorylation of GST-ATF2 (residues 1 to 109) was examined in an immunocomplex kinase assay as described above. The GST-ATF2 was resolved from other proteins by SDS-PAGE and stained with Coomassie blue. The phosphorylation of GST-ATF2 was detected by autoradiography. JNK1-transfected cells, but not mock-transfected cells, phosphorylated ATF2. JNK1 phosphorylation of ATF2 was greater in cells exposed to UV radiation. Phosphorylation of ATF2 by JNK1 was associated with a decreased electrophoretic mobility.

In a separate experiment, GST fusion proteins containing full-length ATF2 (residues 1 to 505), an NH_2-terminal fragment (residues 1 to 109), and a COOH-terminal fragment (residues 95 to 505) were phosphorylated with JNK1 and the sites of phosphorylation analyzed by phosphoamino acid analysis. The methods used for phosphopeptide mapping and phosphoamino acid analysis

have been described (Alvarez et al. (1991) J. Biol. Chem. 266:15277). The horizontal dimension of the peptide maps was electrophoresis and the vertical dimension was chromatography. The NH_2-terminal sites of phosphorylation were identified as Thr^{69} and Thr^{71} by phosphopeptide mapping and mutational analysis. Site-directed mutagenesis was performed as described above, replacing Thr^{69} and Thr^{71} with Ala. Phosphorylation of mutated ATF2 was not observed.

Example 10. Reduced Electrophoretic Mobility of JNK-Activated ATF2

CHO cells were maintained in Ham's F12 medium supplemented with 5% bovine serum albumin (Gibco-BRL). Cells were labeled and transfected with JNK1 as described above. CHO cells were treated with UV-C (40 J/m^2), IL-1α (10 ng/ml) (Genzyme), or fetal bovine serum (20%) (Gibco-BRL). The cells were incubated for 30 minutes at 37°C prior to harvesting. The electrophoretic mobility of ATF2 after SDS-PAGE was examined by protein immuno-blot analysis. A shift in ATF2 electrophoretic mobility was observed in cells treated with UV, IL-1, and serum. These results indicate that JNK1 activation is associated with an electrophoretic mobility shift of ATF2, further suggesting that ATF2 is an *in vivo* substrate for JNK1.

Example 11. Increased ATF2 Phosphorylation After Activation of JNK

COS-1 cells were transfected without (control) and with an ATF2 expression vector (ATF2), as described above (Hai et al. (1989) supra). The effect of exposure of the cells to 40 J/m^2 UV-C was examined. After irradiation, the cells were incubated for 0 or 30 minutes (control) or 0, 15, 30, and 45 minutes (ATF2) at 37°C and then collected. The electrophoretic mobility of ATF2 during

SDS-PAGE was examined by protein immuno-blot analysis as described above. The two electrophoretic mobility forms of ATF2 were observed in ATF2-transfected cells, but not in control cells.

The phosphorylation state of wild-type ($Thr^{69,71}$) ATF2 and mutated ($Ala^{69,71}$) ATF2 was examined in cells labeled with $[^{32}]P$, treated without and with 40 J/m^2 UV-C, and then incubated at 37°C for 30 minutes (Hai et al. (1989) supra). The ATF2 proteins were isolated by immunoprecipitation and analyzed by SDS-PAGE and autoradiography. The phosphorylated ATF2 proteins were examined by phosphoamino acid analysis as described above. Both forms of ATF2 contained phosphoserine, but only wild-type ATF2 contained phosphothreonine.

Tryptic phosphopeptide mapping was used to compare ATF2 phosphorylated *in vitro* by JNK1 with ATF2 phosphorylated in COS-1 cells. A map was also prepared with a sample composed of equal amounts of *in vivo* and *in vitro* phosphorylated ATF2 (Mix). Mutation of ATF2 at Thr^{69} and Thr^{71} resulted in the loss of two tryptic phosphopeptides in maps of ATF2 isolated from UV-irradiated cells. These phosphopeptides correspond to mono- and bis-phosphorylated peptides containing Thr^{69} and Thr^{71}. Both of these phosphopeptides were found in maps of ATF2 phosphorylated by JNK1 *in vitro*.

Example 12. Inhibition of ATF2-Stimulated Gene Expression by Mutation of the Phosphorylation Sites Thr^{69} and Thr^{71}

A fusion protein consisting of ATF2 and the GAL4 DNA binding domain was expressed in CHO cells as described above. The activity of the GAL4-ATF2 fusion protein was measured in co-transfection assays with the reporter plasmid pG5E1bLuc (Seth et al. (1992) J. Biol. Chem. 267:24796. The reporter plasmid contains five GAL4

sites cloned upstream of a minimal promoter element and the firefly luciferase gene. Transfection efficiency was monitored with a control plasmid that expresses β-galactosidase (pCH110; Pharmacia-LKB Biotechnology). The luciferase and β-galactosidase activity detected in cell extracts was measured as the mean activity ratio of three experiments (Gupta et al. (1993) Proc. Natl. Acad. Sci. USA 90:3216). The results, shown in Table 1, demonstrate the importance of phosphorylation at Thr^{69} and Thr^{71} for transcriptional activity.

TABLE 1. INHIBITION OF ATF-2 STIMULATED GENE EXPRESSION BY MUTATION OF THE PHOSPHORYLATION SITES $THR^{69,71}$

PROTEIN	LUCIFERASE ACTIVITY (Light Units/OD)
GAL4	45
GAL4-ATF2 (wild type)	320,000
GAL4-ATF2 (Ala^{69})	24,000
GAL4-ATF2 (Ala^{71})	22,000
GAL4-ATF2 ($Ala^{69,71}$)	29,000
GAL4-ATF2 (Glu^{69})	27,000

Example 13. Effect of Dominant-Negative JNK1 Mutant on ATF2 Function

The luciferase reporter plasmid system was used to determine the effect of point mutations at the ATF2 phosphorylation sites Thr^{69} and Thr^{71} in serum-treated CHO cells transfected with wild-type (Thr^{183}, Tyr^{185}) or mutant (Ala^{183}, Phe^{185}) JNK1. Control experiments were done with mock-transfected cells. The CHO cells were serum-starved for 18 hours and then incubated without or with serum for 4 hours. Expression of wild-type ATF2 caused a small increase in serum-stimulated ATF2 transcriptional activity. In contrast, mutant JNK1 inhibited both control and serum-stimulated ATF2 activity.

Example 14. Effect of Tumor Suppressor Gene Product Rb and Adenovirus Oncoprotein E1A on ATF2-Stimulated Gene Expression

The effect of expression of the Rb tumor suppressor gene product and adenovirus oncoprotein E1A on ATF2 transcriptional activity were investigated with a luciferase reporter plasmid and GAL4-ATF2 (residues 1-505), as described above. Cells were transfected with wild-type ($Thr^{69,71}$) or mutated ($Ala^{69,71}$) ATF2. No effect of Rb or E1A on luciferase activity was detected in the absence of GAL4-ATF2. Rb and E1A were found to increase ATF2-stimulated gene expression of both wild-type and mutated ATF2. However, mutated ATF2 caused a lower level of reporter gene expression than did wild-type ATF2. These results indicate a requirement for ATF2 phosphorylation (on Thr^{69} and Thr^{71}) plus either Rb or E1A for maximal transcriptional activity.

Example 15. Substrate Specificity of p38 MAP Kinase

Substrate phosphorylation by p38 MAP kinase was examined by incubation of bacterially-expressed p38 MAP kinase with IκB, cMyc, EGF-R, cytoplasmic phospholipase A_2 ($cPLA_2$), c-Jun, and mutated ATF2 ($Thr^{69,71}$) and ATP[γ-^{32}P] (Raingeaud et al. (1995) J. Biol. Chem 270:7420. GST-IκB was provided by Dr D. Baltimore (Massachusetts Institute of Technology). GST-cMyc (Alvarez et al. (1991) J. Biol. Chem. 266:15277), GST-EGF-R (residues 647-688) (Koland et al. (1990) Biochem. Biophys. Res. Commun. 166:90), and GST-c-Jun (Dérijard et al. (1994) supra) have been described. The phosphorylation reaction was terminated after 30 minutes by addition of Laemmli sample buffer. The phosphorylated proteins were resolved by SDS-PAGE and detected by autoradiography. The rate phosphorylation of the substrate proteins was quantitated by PhosphorImager (Molecular Dynamics Inc.) analysis.

The relative phosphorylation of ATF2, MBP, EGF-R, and IκB was 1.0, 0.23, 0.04, and 0.001, respectively.

Example 16. Binding of p38 MAP Kinase to ATF2

Cell extracts expressing epitope-tagged JNK1 and p38 MAP kinase were incubated with a GST fusion protein containing the activation domain of ATF2 (residues 1-109) immobilized on GSH agarose. The supernatant was removed and the agarose was washed extensively. Western blot analysis of the supernatant and agarose-bound fractions was conducted as follows: proteins were fractionated by SDS-PAGE, electrophoretically transferred to an Immobilon-P membrane, and probed with monoclonal antibodies to phosphotyrosine (PY20) and the Flag epitope (M2). Immunocomplexes were detected using enhanced chemiluminescence (Amersham International PLC). Control experiments were performed using immobilized GST.

Example 17. p38 MAP Kinase and JNK1 Activation by Pro-Inflammatory Cytokines and Environmental Stress

The effect of phorbol ester, EGF, UV radiation, osmotic stress, IL-1, tumor necrosis factor (TNF), and LPS on p38 MAP kinase and JNK1 activity were measured in immunecomplex protein kinase assays using ATP[γ-^{32}P] and ATF2 as substrates. TNFα and IL-1α were from Genzyme Corp. Lipolysaccharide (LPS) was isolated from lyophilized *Salmonella minesota* Re595 bacteria as described (Mathison et a. (1988) J. Clin. Invest. 81:1925). Phorbol myristate acetate was from Sigma. EGF was purified from mouse salivary glands (Davis (1988) J. Biol. Chem. 263:9462). Kinase assays were performed using immunoprecipitates of p38 and JNK. The immunocomplexes were washed twice with kinase buffer (described above), and the assays initiated by the

addition of 1 μg of ATF2 and 50 μM [γ-^{32}P]ATP (10 Ci/mmol) in a final volume of 25 μl. The reactions were terminated after 30 minutes at 30°C by addition of Laemmli sample buffer. The phosphorylation of ATF2 was examined after SDS-PAGE by autoradiography, and the rate of ATF2 phosphorylation quantitated by PhosphorImager analysis.

The results are shown in Table 2. Exposure of HeLa cells to 10 nM phorbol myristate acetate very weakly activated p38 and JNK1. Similarly, treatment with 10 nM EGF only weakly activated p38 and JNK1. By contrast, treatment with 40 J/m^2 UV-C, 300 mM sorbitol, 10 ng/ml interleukin-1, and 10 ng/ml TNFα strongly activated p38 and JNK1 activity. The effect of LPS on the activity of p38 was examined using CHO cells that express human CD14. Exposure of CHO cells to 10 ng/ml LPS only slightly activated p38 and JNK1 activity.

TABLE 2. p38 AND JNK1 ACTIVATION BY PRO-INFLAMMATORY CYTOKINES AND ENVIRONMENTAL STRESS.

	Relative Protein Kinase Activity	
	JNK	p38
Control	1.0	1.0
Epidermal Growth Factor (10 nM)	1.9	2.1
Phorbol Ester (10 nM)	2.3	2.9
Lipopolysaccharide (10 ng/ml)	3.6	3.7
Osmotic Shock (300 mM sorbitol)	18.1	4.2
Tumor Necrosis Factor (10 ng/ml)	19.3	10.3
Interleukin-1 (10 ng/ml)	8.9	6.2
UV (40 J/m^2)	7.4	17.1

Example 18. <u>p38 MAP Kinase Activation by Dual Phosphorylation on Tyr and Thr</u>

COS-1 cells expressing wild-type (Thr^{180}, Tyr^{182}) or mutated (Ala^{180}, Phe^{182}) p38 MAP kinase were treated

without and with UV-C (40 J/m^2). The cells were harvested 30 minutes following exposure with or without UV radiation. Control experiments were performed using mock-transfected cells. The level of expression of epitope-tagged p38 MAP kinase and the state of Tyr phosphorylation of p38 MAP kinase was examined by Western blot analysis using the M2 monoclonal antibody and the phosphotyrosine monoclonal antibody PY20. Immune complexes were detected by enhanced chemiluminescence.

Wild-type and mutant p38 were expressed at similar levels. Western blot analysis showed that UV radiation caused an increase in the Tyr phosphorylation of p38. The increased Tyr phosphorylation was confirmed by phosphoamino acid analysis of p38 isolated from [^{32}P]phosphate-labeled cells. The results also showed that UV radiation increased Thr phosphorylation of p38. The increased phosphorylation on Tyr and Thr was blocked by mutated p38. Wild-type and mutated p38 were isolated from the COS-1 cells by immunoprecipitation. Protein kinase activity was measured in the immune complex using [γ-^{32}P]ATP and GST-ATF2 as substrates. The phosphorylated GST-ATF2 was detected after SDS-PAGE by autoradiography. UV radiation resulted in a marked increase in the activity of wild-type p38, while the mutant p38 was found to be catalytically inactive. These results show that p38 is activated by dual phosphorylation within the Thr-Gly-Tyr motif.

Example 19. <u>MAP Kinase Phosphatase Inhibits p38 MAP Kinase Activation</u>

The cells were treated without and with 40 J/m^2 UV-C. Control experiments were performed using mock-transfected cells (control) and cells transfected with the catalytically inactive mutated phosphatase mPAC1 (Cys^{257}/Ser) and human MKP1. The activity of p38 MAP

kinase was measured with an immunecomplex protein kinase assay employing [γ-^{32}P]ATP and GST-ATF2 as substrates. The expression of PAC1 or MKP1 was found to inhibit p38 phosphorylation, demonstrating that p38 can be regulated by the dual specificity phosphatases PAC1 and MKP1.

Example 20. Subcellular Distribution of p38 MAP Kinase

Epitope-tagged p38 MAP kinase was expressed in COS cells. The cells were treated without or with 40 J/m^2 UV radiation and then incubated for 60 minutes at 37°C. The p38 MAP kinase was detected by indirect immunofluorescence using the M2 monoclonal antibody. The images were acquired by digital imaging microscopy and processed for image restoration.

Immunocytochemistry. Coverslips (22mm x 22mm No. 1; Gold Seal Cover Glass; Becton-Dickinson) were pre-treated by boiling in 0.1 N HCl for 10 minutes, rinsed in distilled water, autoclaved and coated with 0.01% poly-L-lysine (Sigma; St. Louis MO). The coverslips were placed at the bottom of 35 mm multiwell tissue culture plates (Becton Dickinson, UK). Transfected COS-1 cells were plated directly on the coverslips and allowed to adhere overnight in Dulbecco's modified Eagle's medium supplemented with 5% fetal calf serum (Gibco-BRL). 24 hours post-transfection, the cells were rinsed once and incubated at 37°C for 30 minutes in 25 mM Hepes, pH 7.4, 137 mM NaCl, 6 mM KCl, 1 mM $MgCl_2$, 1 mM $CaCl_2$, 10 mM glucose. The cells were rinsed once with phosphate-buffered saline and the coverslips removed from the tissue culture wells. Cells were fixed in fresh 4% paraformaldehyde in phosphate-buffered saline for 15 minutes at 22°C. The cells were permeabilized with 0.25% Triton X-100 in phosphate-buffered saline for 5 minutes and washed three times in DWB solution (150 mM NaCl, 15 mM Na citrate, pH 7.0, 2% horse serum, 1% (w/v) bovine

serum albumin, 0.05% Triton X-100) for 5 minutes. The primary antibody (M2 anti-FLAG monoclonal antibody, Eastman-Kodak Co., New Haven, CT) was diluted 1:250 in DWB and applied to the cells in a humidified environment at 22°C for 1 hour. The cells were again washed three times as above and fluorescein isothiocyanate-conjugated goat anti-mouse Ig secondary antibody (Kirkegaard & Perry Laboratories Inc. Gaithersburg, MD) was applied at a 1:250 dilution for 1 hour at 22°C in a humidified environment. The cells were then washed three times in DWB and then mounted onto slides with Gel-Mount (Biomeda Corp. Foster City, CA) for immunofluorescence analysis. Control experiments were performed to assess the specificity of the observed immunofluorescence. No fluorescence was detected when the transfected cells were stained in the absence of the primary M2 monoclonal antibody, or mock-transfected cells.

Digital Imaging Microscopy and Image Restoration

Digital images of the fluorescence distribution in single cells were obtained using a Nikon 60x Planapo objective (numerical aperture = 1.4) on a Zeiss IM-35 microscope equipped for epifluorescence as previously described (Carrington et al. (1990) in: Non-invasive Techniques in Cell Biology (Fosbett & Grinstein, eds.), Wiley-Liss, NY; pp. 53-72; Fay et al. (1989) J. Microsci. 153:133-149). Images of various focal planes were obtained with a computer controlled focus mechanism and a thermoelectrically cooled charged-coupled device camera (model 220; Photometrics Ltd., Tucson, AZ). The exposure of the sample to the excitation source was determined by a computer-controlled shutter and wavelength selector system (MVI, Avon, MA). The charge-coupled device camera and microscope functions were controlled by a microcomputer, and the data acquired from the camera were transferred to a Silicon Graphics model 4D/GTX

workstation (Mountainview, CA) for image processing. Images were corrected for non-uniformities in sensitivity and for the dark current of the charge coupled device detector. The calibration of the microscopy blurring was determined by measuring the instrument's point spread function as a series of optical sections at 0.125μm intervals of a 0.3 μm diameter fluorescently labeled latex bead (Molecular Probes Inc.). The image restoration algorithm used is based upon the theory of ill-posed problems and obtains quantitative dye density values within the cell that are substantially more accurate than those in an un-processed image (Carrington et al. (1990) supra; Fay et al. (1989) supra). After image processing, individual optical sections of cells were inspected and analyzed using computer graphics software on a Silicon Graphics workstation. p38 MAP kinase was observed at the cell surface, in the cytoplasm, and in the nucleus. After irradiation, an increased localization of cytoplasmic p38 to the perinuclear region was detected.

Example 21. Activation of the MKK Signal Transduction Pathway by Osmotic Shock

CHO cells were co-transfected with the plasmid pCMV-Flag-Jnk1 and pRSV-Neo (Dérijard et al. (1994) supra). A stable cell line expressing epitope-tagged Jnk1 (Flag; Immunex Corp.) was isolated by selection with Geneticin (Gibco-BRL). The cells were incubated with 0, 100, 150, 300, 600, or 1000 mM sorbitol for 1 hour at 37°C. The cells were collected in lysis buffer (20 mM Tris, pH 7.4, 1% Triton X-100, 2 mM EDTA, 137 mM NaCl, 25 mM β-glycerophosphate, 1 mM orthovanadate, 2 mM pyrophosphate, 10% glycerol, 1 mM phenylmethylsulfonyl fluoride, 10 μg/ml leupeptin) and a soluble extract was obtained by centrifugation at 100,000 g for 30 minutes at

4°C. The epitope-tagged JNK1 was isolated by immunoprecipitation with the monoclonal antibody M2 (Immunex Corp.). The immunoprecipitates were washed extensively with lysis buffer. Immunecomplex kinase assays were done in 25 μl of 25 mM Hepes, pH 7.4, 25 mM $MgCl_2$, 25 mM β-glycerophosphate, 2 mM dithiothreitol, 100 μM orthovanadate, and 50 μM ATP [γ-^{32}P] (10 Ci/mmole) with 2.5 μg of bacterially expressed c-Jun (residues 1-79) fused to glutathione-S-transferase (GST) as a substrate. The phosphorylation of c-Jun was examined after SDS-PAGE by autoradiography and PhosphorImager (Molecular Dynamics Inc.) analysis. JNK1 activation was observed at all concentrations of sorbitol exposure.

The time course of JNK1 protein kinase activation was measured in cells incubated in medium supplemented with 300 mM sorbitol as described above. Increased JNK1 activity was observed within 5 minutes of exposure to sorbitol, with maximum activity occurring after 15-30 minutes.

Mutation of JNK1 at the phosphorylation sites Thr^{183} and Tyr^{185} blocked the activation of JNK1 protein kinase activity by osmotic shock. CHO cells were transfected with vector, wild-type JNK1 (Thr^{183}, Tyr^{185}), and mutated JNK1 (Ala^{183}, Phe^{185}). The cells were incubated in medium supplemented without or with 300 mM sorbitol for 15 minutes before measurement of JNK1 protein kinase activity as described above. JNK1 activation was seen in the wild-type but not mutated JNK1.

Use

The MKK polypeptides and polynucleotides of the invention are useful for identifying reagents which modulate the MKK signal transduction pathways. Reagents that modulate an MKK signal transduction pathway can be

identified by their effect on MKK synthesis, MKK phosphorylation, or MKK activity. For example, the effect of a reagent on MKK activity can be measured by the *in vitro* kinase assays described above. MKK is incubated without (control) and with a test reagent under conditions sufficient to allow the components to react, then the effect of the test reagent on kinase activity is subsequently measured. Reagents that inhibit an MKK signal transduction pathway can be used in the treatment of MKK-mediated disorders. Reagents that stimulate an MKK signal transduction pathway can be used in a number of ways, including induction of programmed cell death (apoptosis) in tissues. For example, the elimination of UV damaged cells can be used to prevent cancer.

Generally, for identification of a reagent that inhibits the MKK signal transduction pathway, the kinase assay is tested with a range of reagent concentrations, e.g., 1.0 nM to 100 mM, a MKK substrate, and a radioactive marker such as [γ-^{32}P]ATP. Appropriate substrate molecules include p38, JNK1, JNK2, or ATF2. The incorporation of [^{32}]P into the substrate is determined, and the results obtained with the test reagent compared to control values. Of particular interest are reagents that result in inhibition of [^{32}]P of about 80% or more.

Assays that test the effect of a reagent on MKK synthesis can also be used to identify compounds that inhibit MKK signal transduction pathways. The effect of the test reagent on MKK expression is measured by, for example, Western blot analysis with an antibody specific for MKK. Antibody binding is visualized by autoradiography or chemiluminescence, and is quantitated. The effect of the test reagent on MKK mRNA expression can be examined, for example, by Northern blot analysis using a polynucleotide probe or by polymerase chain reaction.

Reagents found to inhibit MKK signal transduction pathways can be used as therapeutic agents for the treatment of MKK-mediated disorders. Such reagents are also useful in drug design for elucidation of the specific molecular features needed to inhibit MKK signal transduction pathways.

In addition, the invention provides a method for the treatment of MKK-mediated stress-related and inflammatory disorders. The method includes administration of an effective amount of a therapeutic reagent that inhibits MKK function. Suitable reagents inhibit either MKK activity or expression. The concentration of the reagent to be administered is determined based on a number of factors, including the appropriate dosage, the route of administration, and the specific condition being treated. The appropriate dose of a reagent is determined by methods known to those skilled in the art including routine experimentation to optimize the dosage as necessary for the individual patient and specific MKK-mediated disorder being treated. Specific therapeutically effective amounts appropriate for administration are readily determined by one of ordinary skill in the art (see, for example, Remington's Pharmaceutical Sciences. 18th ed., Gennaro, ed., Mack Publishing Company, Easton, PA, 1990).

The invention provides methods for both acute and prophylactic treatment of stress-related and inflammatory disorders. For example, it is envisioned that ischemic heart disease will be treated during episodes of ischemia and oxidative stress following reperfusion. In addition, a patient at risk for ischemia can be treated prior to ischemic episodes.

In another example, a therapeutic agent which inhibits MKK function or activity is administered to control inflammatory responses by inhibiting the

secretion of inflammatory cytokines, including TNF and IL-1.

Stress-related proliferative disorders can also be treated by the method of the invention by administering a therapeutic reagent that inhibits MKK function or activity. Such therapeutic reagents can be used alone or in combination with other therapeutic reagents, for example, with chemotherapeutic agents in the treatment of malignancies. Indeed, the control of stress-activated MKK by the therapeutic reagents provided by this invention can modulate symptoms caused by other therapeutic strategies that induce stress.

The therapeutic reagents employed are compounds which inhibit MKK function or activity, including polynucleotides, polypeptides, and other molecules such as antisense oligonucleotides and ribozymes, which can be made according to the invention and techniques known to the art. Polyclonal or monoclonal antibodies (including fragments or derivatives thereof) that bind epitopes of MKK also can be employed as therapeutic reagents. Dominant-negative forms of MKK which effectively displace or compete with MKK for substrate binding and/or phosphorylation can be used to decrease protein kinase activity. Dominant-negative forms can be created by mutations within the catalytic domain of the protein kinases, as described above.

In some cases, augmentation of MKK activity is desirable, e.g., induction of apoptosis. The methods of the invention can be used to identify reagents capable of increasing MKK function or activity. Alternatively, increased activity is achieved by over-expression of MKK. When a MKK-mediated disorder is associated with underexpression of MKK, or expression of a mutant MKK polypeptide, a sense polynucleotide sequence (the DNA

coding strand) or MKK polypeptide can be introduced into the cell.

The antibodies of the invention can be administered parenterally by injection or by gradual infusion over time. The monoclonal antibodies of the invention can be administered intravenously, intraperitoneally, intramuscularly, subcutaneously, intracavity, or transdermally.

Preparations for parenteral administration of a polypeptide or an antibody of the invention include sterile aqueous or non-aqueous solutions, suspensions, and emulsions. Examples of non-aqueous solvents are propylene glycol, polyethylene glycol, vegetable oils such as olive oil, and injectable organic esters such as ethyl oleate. Aqueous carriers include water, alcoholic/aqueous solutions, emulsions or suspensions, including saline and buffered media. Parenteral vehicles include sodium chloride solution, Ringer's dextrose, dextrose and sodium chloride, lactated Ringer's, or fixed oils. Intravenous vehicles include fluid and nutrient replenishers, electrolyte replenishers (such as those based on Ringer's dextrose) and the like. Preservatives and other additives can also be present, such as, for example, antimicrobials, antioxidants, chelating agents, and inert gases, and the like.

Polynucleotide sequences, including antisense sequences, can be therapeutically administered by various techniques known to those skilled in the art. Such therapy would achieve its therapeutic effect by introduction of the MKK polynucleotide into cells of mammals having a MKK-mediated disorder. Delivery of MKK polynucleotides can be achieved using free polynucleotide or a recombinant expression vector such as a chimeric virus or a colloidal dispersion system. Especially

preferred for therapeutic delivery of nucleotide sequences is the use of targeted liposomes.

Targeting of the therapeutic reagent to specific tissues is desirable to increase the efficiency of delivery. The targeting can be achieved by passive mechanisms via the route of administration. Active targeting to specific tissues can also be employed. The use of liposomes, colloidal suspensions, and viral vectors allows targeting to specific tissues by changing the composition of the formulation containing the therapeutic reagent, for example, by including molecules that act as receptors for components of the target tissues. Examples include sugars, glycoplipids, polynucleotides, or proteins. These molecules can be included with the therapeutic reagent. Alternatively, these molecules can be included by indirect methods, for example, by inclusion of a polynucleotide that encodes the molecule, or by use of packaging systems that provide targeting molecules. Those skilled in the art will know, or will ascertain with the use of the teaching provided herein, which molecules and procedures will be useful for delivery of the therapeutic reagent to specific tissues.

Other Embodiments

It is to be understood that while the invention has been described in conjunction with the detailed description thereof, that the foregoing description is intended to illustrate and not limit the scope of the invention, which is defined by the scope of the appended claims. Other aspects, advantages, and modifications are within the scope of the following claims.

SEQUENCE LISTING

(1) GENERAL INFORMATION:

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Derijard, Benoit

(ii) TITLE OF INVENTION: CYTOKINE-, STRESS-, AND ONCOPROTEIN-ACTIVATED HUMAN PROTEIN KINASE KINASES

(iii) NUMBER OF SEQUENCES: 16

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(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:
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(B) FILING DATE: 19-SEP-1995
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(viii) ATTORNEY/AGENT INFORMATION:
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(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 2030 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

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GCGAGGAGCG TGGTCCCCAC CCATCCAGCC CATATGTGCA AGTGCCCTTG ACAGAGAGGC 180

TGGTCATATC CATGGTGACC ATTTATGGGC CACAACAGGT CCCCATCTGC GCAGTGAACC 240

CTGTGCTGAG CACCTTGCAG ACGTGATCTT GCTTCGTCCT GCAGCACTGT GCGGGGCAGG 300

AAAATCCAAG AGGAAGAAGG ATCTACGGAT ATCCTGCATG TCCAAGCCAC CCGCACCCAA 360

CCCCACACCC CCCCGGAACC TGGACTCCCG GACCTTCATC ACCATTGGAG ACAGAAACTT 420

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CATGATTGAG ATGGCCATCC TGCGGTTCCC TTACGAGTCC TGGGGGACCC CGTTCCAGCA 1080

GCTGAAGCAG GTGGTGGAGG AGCCGTCCCC CCAGCTCCCA GCCGACCGTT TCTCCCCCGA 1140

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GCGAGCCATT TGTCCCAAGT GCCAAAGAAG CAGACCATTG GGGCTCCCAG CCAGGCCCTT 1500

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CAGTGCCTGG GTGGATGGGC CACCGCCTTG CCCAGCCTGG ATGCCATCCA AGTTGTATAT 1680

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TTTTTCTTGC ATGGTTTGGA GCTGATCGCT TCTCCCCCAC CCCCTAGGGG 2030

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 318 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

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Ser Arg Thr Phe Ile Thr Ile Gly Asp Arg Met Phe Glu Val Glu Ala
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Asp Asp Leu Val Thr Ile Ser Glu Leu Gly Arg Gly Ala Tyr Gly Val
35 40 45

Val Glu Lys Val Arg His Ala Gln Ser Gly Thr Ile Met Ala Val Lys
50 55 60

Arg Ile Arg Ala Thr Val Asn Ser Gln Glu Gln Lys Arg Leu Leu Met
65 70 75 80

Asp Leu Asp Ile Asn Met Arg Thr Val Asp Cys Phe Tyr Thr Val Thr
85 90 95

Phe Tyr Gly Ala Leu Phe Arg Glu Gly Asp Val Trp Ile Cys Met Glu
100 105 110

Leu Met Asp Thr Ser Leu Asp Lys Phe Tyr Arg Lys Val Leu Asp Lys
115 120 125

Asn Met Thr Ile Pro Glu Asp Ile Leu Gly Glu Ile Ala Val Ser Ile
130 135 140

Val Arg Ala Leu Glu His Leu His Ser Lys Leu Ser Val Ile His Arg
145 150 155 160

Asp Val Lys Pro Ser Asn Val Leu Ile Asn Lys Glu Gly His Val Lys
165 170 175

Met Cys Asp Phe Gly Ile Ser Gly Tyr Leu Val Asp Ser Val Ala Lys
180 185 190

Thr Met Asp Ala Gly Cys Lys Pro Tyr Met Ala Pro Glu Arg Ile Asn
195 200 205

Pro Glu Leu Asn Gln Lys Gly Tyr Asn Val Lys Ser Asp Val Trp Ser
210 215 220

Leu Gly Ile Thr Met Ile Glu Met Ala Ile Leu Arg Phe Pro Tyr Glu
225 230 235 240

Ser Trp Gly Thr Pro Phe Gln Gln Leu Lys Gln Val Val Glu Glu Pro
245 250 255

Ser Pro Gln Leu Pro Ala Asp Arg Phe Ser Pro Glu Phe Val Asp Phe
260 265 270

Thr Ala Gln Cys Leu Arg Lys Asn Pro Ala Glu Arg Met Ser Tyr Leu
275 280 285

Glu Leu Met Glu His Pro Phe Phe Thr Leu His Lys Thr Lys Lys Thr
290 295 300

Asp Ile Ala Ala Phe Val Lys Lys Ile Leu Gly Glu Asp Ser
305 310 315

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 1602 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

TAGCTGCAGC ACAGCCTTCC CTAACGTTGC AACTGGGGGA AAAATCACTT TCCAGTCTGT 60

TTTGCAAGGT GTGCATTTCC ATCTTGATTC CCTGAAAGTC CATCTGCTGC ATCGGTCAAG 120

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CTACAGAAGA GAAGCAAGGC AAAGTCTTTT GTGCTCCCCT CCCCCATCAA AGGAAAGGGG 240

AAAATGTCTC AGTCGAAAGG CAAGAAGCGA AACCCTGGCC TTAAAATTCC AAAAGAAGCA 300

TTTGAACAAC CTCAGACCAG TTCCACACCA CCTAGAGATT TAGACTCCAA GGCTTGCATT 360

TCTATTGGAA ATCAGAACTT TGAGGTGAAG GCAGATGACC TGGAGCCTAT AATGGAACTG 420

GGACGAGGTG CGTACGGGGT GGTGGAGAAG ATGCGGCACG TGCCCAGCGG GCAGATCATG 480

GCAGTGAAGC GGATCCGAGC CACAGTAAAT AGCCAGGAAC AGAAACGGCT ACTGATGGAT 540

TTGGATATTT CCATGAGGAC GGTGGACTGT CCATTCACTG TCACCTTTTA TGGCGCACTG 600

TTTCGGGAGG GTGATGTGTG GATCTGCATG GAGCTCATGG ATACATCACT AGATAAATTC 660

TACAAACAAG TTATTGATAA AGGCCAGACA ATTCCAGAGG ACATCTTAGG GAAAATAGCA 720

GTTTCTATTG TAAAAGCATT AGAACATTTA CATAGTAAGC TGTCTGTCAT TCACAGAGAC 780

GTCAAGCCTT CTAATGTACT CATCAATGCT CTCGGTCAAG TGAAGATGTG CGATTTTGGA 840

ATCAGTGGCT ACTTGGTGGA CTCTGTTGCT AAAACAATTG ATGCAGGTTG CAAACCATAC 900

ATGGCCCCTG AAAGAATAAA CCCAGAGCTC AACCAGAAGG GATACAGTGT GAAGTCTGAC 960

ATTTGGAGTC TGGGCATCAC GATGATTGAG TTGGCCATCC TTCGATTTCC CTATGATTCA 1020

TGGGGAACTC CATTTCAGCA GCTCAAACAG GTGGTAGAGG AGCCATCGCC ACAACTCCCA 1080

GCAGACAAGT TCTCTGCAGA GTTTGTTGAC TTTACCTCAC AGTGCTTAAA GAAGAATTCC 1140

AAAGAACGGC CTACATACCC AGAGCTAATG CAACATCCAT TTTTCACCCT ACATGAATCC 1200

AAAGGAACAG ATGTGGCATC TTTTGTAAAA CTGATTCTTG GAGACTAAAA AGCAGTGGAC 1260

TTAATCGGTT GACCCTACTG TGGATTGGTG GGTTTCGGGG TGAAGCAAGT TCACTACAGC 1320

ATCAATAGAA AGTCATCTTT GAGATAATTT AACCCTGCCT CTCAGAGGGT TTTCTCTCCC 1380

AATTTTCTTT TTACTCCCCC TCTTAAGGGG GCCTTGGAAT CTATAGTATA GAATGAACTG 1440

TCTAGATGGA TGAATTATGA TAAAGGCTTA GGACTTCAAA AGGTGATTAA ATATTTAATG 1500

ATGTGTCATA TGAGTCCTCA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA 1560

AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AA 1602

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 334 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

Met Ser Gln Ser Lys Gly Lys Lys Arg Asn Pro Gly Leu Lys Ile Pro
1 5 10 15

Lys Glu Ala Phe Glu Gln Pro Gln Thr Ser Ser Thr Pro Pro Arg Asp
20 25 30

Leu Asp Ser Lys Ala Cys Ile Ser Ile Gly Asn Gln Asn Phe Glu Val
35 40 45

Lys Ala Asp Asp Leu Glu Pro Ile Met Glu Leu Gly Arg Gly Ala Tyr
50 55 60

Gly Val Val Glu Lys Met Arg His Val Pro Ser Gly Gln Ile Met Ala
65 70 75 80

Val Lys Arg Ile Arg Ala Thr Val Asn Ser Gln Glu Gln Lys Arg Leu
85 90 95

Leu Met Asp Leu Asp Ile Ser Met Arg Thr Val Asp Cys Pro Phe Thr
100 105 110

Val Thr Phe Tyr Gly Ala Leu Phe Arg Glu Gly Asp Val Trp Ile Cys
115 120 125

Met Glu Leu Met Asp Thr Ser Leu Asp Lys Phe Tyr Lys Gln Val Ile
130 135 140

Asp Lys Gly Gln Thr Ile Pro Glu Asp Ile Leu Gly Lys Ile Ala Val
145 150 155 160

Ser Ile Val Lys Ala Leu Glu His Leu His Ser Lys Leu Ser Val Ile
165 170 175

His Arg Asp Val Lys Pro Ser Asn Val Leu Ile Asn Ala Leu Gly Gln
180 185 190

Val Lys Met Cys Asp Phe Gly Ile Ser Gly Tyr Leu Val Asp Ser Val
195 200 205

Ala Lys Thr Ile Asp Ala Gly Cys Lys Pro Tyr Met Ala Pro Glu Arg
210 215 220

Ile Asn Pro Glu Leu Asn Gln Lys Gly Tyr Ser Val Lys Ser Asp Ile
225 230 235 240

Trp Ser Leu Gly Ile Thr Met Ile Glu Leu Ala Ile Leu Arg Phe Pro
245 250 255

Tyr Asp Ser Trp Gly Thr Pro Phe Gln Gln Leu Lys Gln Val Val Glu
260 265 270

Glu Pro Ser Pro Gln Leu Pro Ala Asp Lys Phe Ser Ala Glu Phe Val
275 280 285

Asp Phe Thr Ser Gln Cys Leu Lys Lys Asn Ser Lys Glu Arg Pro Thr
290 295 300

Tyr Pro Glu Leu Met Gln His Pro Phe Phe Thr Leu His Glu Ser Lys
305 310 315 320

Gly Thr Asp Val Ala Ser Phe Val Lys Leu Ile Leu Gly Asp
325 330

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 3497 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

CTAGGGTCCC CGGCGCCAGG CCACCCGGCC GTCAGCAGCA TGCAGGGTAA ACGCAAAGCA 60

CTGAAGTTGA ATTTTGCAAA TCCACCTTTC AAATCTACAG CAAGGTTTAC TCTGAATCCC 120

AATCCTACAG GAGTTCAAAA CCCACACATA GAGAGACTGA GAACACACAG CATTGAGTCA 180

TCAGGAAAAC TGAAGATCTC CCCTGAACAA CACTGGGATT TCACTGCAGA GGACTTGAAA 240

GACCTTGGAG AAATTGGACG AGGAGCTTAT GGTTCTGTCA ACAAAATGGT CCACAAACCA 300

AGTGGGCAAA TAATGGCAGT TAAAAGAATT CGGTCAACAG TGGATGAAAA AGAACAAAAA 360

CAACTTCTTA TGGATTTGGA TGTAGTAATG CGGAGTAGTG ATTGCCCATA CATTGTTCAG 420

TTTTATGGTG CACTCTTCAG AGAGGGTGAC TGTTGGATCT GTATGGAACT CATGTCTACC 480

TCGTTTGATA AGTTTTACAA ATATGTATAT AGTGTATTAG ATGATGTTAT TCCAGAAGAA 540

ATTTTAGGCA AAATCACTTT AGCAACTGTG AAAGCACTAA ACCACTTAAA AGAAAACTTG 600

AAAATTATTC ACAGAGATAT CAAACCTTCC AATATTCTTC TGGACAGAAG TGGAAATATT 660

AAGCTCTGTG ACTTCGGCAT CAGTGGACAG CTTGTGGACT CTATTGCCAA GACAAGAGAT 720

GCTGGCTGTA GGCCATACAT GGCACCTGAA AGAATAGACC CAAGCGCATC ACGACAAGGA 780

TATGATGTCC GCTCTGATGT CTGGAGTTTG GGGATCACAT TGTATGAGTT GGCCACAGGC 840

CGATTTCCTT ATCCAAAGTG GAATAGTGTA TTTGATCAAC TAACACAAGT CGTGAAAGGA 900

GATCCTCCGC AGCTGAGTAA TTCTGAGGAA AGGGAATTCT CCCCGAGTTT CATCAACTTT 960

GTCAACTTGT GCCTTACGAA GGATGAATCC AAAAGGCCAA AGTATAAAGA GCTTCTGAAA 1020

CATCCCTTTA TTTTGATGTA TGAAGAACGT GCCGTTGAGG TCGCATGCTA TGTTTGTAAA 1080

ATCCTGGATC AAATGCCAGC TACTCCCAGC TCTCCCATGT ATGTCGATTG ATATCGTGCT 1140

ACATCAGACT CTAGAAAAAA GGGCTGAGAG GAAGCAAGAC GTAAAGAATT TTCATCCCGT 1200

ATCACAGTGT TTTTATTGCT CGCCCAGACA CCATGTGCAA TAAGATTGGT GTTCGTTTCC 1260

ATCATGTCTG TATACTCCTG TCACCTAGAA CGTGCATCCT TGTAATACCT GATTGATCAC 1320

ACAGTGTTAG TGCTGGTCAG AGAGACCTCA TCCTGCTCTT TTGTGATGAA CATATTCATG 1380

AAATGTGGAA GTCAGTACGA TCAAGTTGTT GACTGTGATT AGATCACATC TTAAATTCAT 1440

TTCTAGACTC AAAACCTGGA GATGCAGCTA CTGGAATGGT GTTTTGTCAG ACTTCCAAAT 1500

CCTGGAAGGA CACAGTGATG AATGTACTAT ATCTGAACAT AGAAACTCGG GCTTGAGTGA 1560

GAAGAGCTTG CACAGCCAAC GAGACACATT GCCTTCTGGA GCTGGGAGAC AAAGGAGGAA 1620

TTTACTTTCT TCACCAAGTG CAATAGATTA CTGATGTGAT ATTCTGTTGC TTTACAGTTA 1680

CAGTTGATGT TTGGGGATCG ATGTGCTCAG CCAAATTTCC TGTTTGAAAT ATCATGTTAA 1740

ATTAGAATGA ATTTATCTTT ACCAAAAACC ATGTTGCGTT CAAAGAGGTG AACATTAAAA 1800

TATAGAGACA GGACAGAATG TGTTCTTTTC TCCTCTACCA GTCCTATTTT TCAATGGGAA 1860

GACTCAGGAG TCTGCCACTT GTCAAAGAAG GTGCTGATCC TAAGAATTTT TCATTCTCAG 1920

AATTCGGTGT GCTGCCAACT TGATGTTCCA CCTGCCACAA ACCACCAGGA CTGAAAGAAG 1980

AAAACAGTAC AGAAGGCAAA GTTTACAGAT GTTTTTAATT CTAGTATTTT ATCTGGAACA 2040

ACTTGTAGCA GCTATATATT TCCCCTTGGT CCCAAGCCTG ATACTTTAGC CATCATAACT 2100

CACTAACAGG GAGAAGTAGC TAGTAGCAAT GTGCCTTGAT TGATTAGATA AAGATTTCTA 2160

GTAGGCAGCA AAAGACCAAA TCTCAGTTGT TTGCTTCTTG CCATCACTGG TCCAGGTCTT 2220

CAGTTTCCGA ATCTCTTTCC CTTCCCCTGT GGTCTATTGT CGCTATGTGA CTTGCGCTTA 2280

ATCCAATATT TTGCCTTTTT TCTATATCAA AAAACCTTTA CAGTTAGCAG GGATGTTCCT 2340

TACCGAGGAT TTTTAACCCC CAATCTCTCA TAATCGCTAG TGTTTAAAAG GCTAAGAATA 2400

GTGGGGCCCA ACCGATGTGG TAGGTGATAA AGAGGCATCT TTTCTAGAGA CACATTGGAC 2460

CAGATGAGGA TCCGAAACGG CAGCCTTTAC GTTCATCACC TGCTAGAACC TCTCGTAGTC 2520

CATCACCATT TCTTGGCATT GGAATTCTAC TGGAAAAAAA TACAAAAAGC AAAACAAAAC 2580

CCTCAGCACT GTTACAAGAG GCCATTTAAG TATCTTGTGC TTCTTCACTT ACCCATTAGC 2640

CAGGTTCTCA TTAGGTTTTG CTTGGGCCTC CCTGGCACTG AACCTTAGGC TTTGTATGAC 2700

AGTGAAGCAG CACTGTGAGT GGTTCAAGCA CACTGGAATA TAAAACAGTC ATGGCCTGAG 2760

ATGCAGGTGA TGCCATTACA GAACCAAATC GTGGCACGTA TTGCTGTGTC TCCTCTCAGA 2820

GTGACAGTCA TAAATACTGT CAAACAATAA AGGGAGAATG GTGCTGTTTA AAGTCACATC 2880

CCTGTAAATT GCAGAATTCA AAAGTGATTA TCTCTTTGAT CTACTTGCCT CATTTCCCTA 2940

TCTTCTCCCC CACGGTATCC TAAACTTTAG ACTTCCCACT GTTCTGAAAG GAGACATTGC 3000

TCTATGTCTG CCTTCGACCA CAGCAAGCCA TCATCCTCCA TTGCTCCCGG GGACTCAAGA 3060

GGAATCTGTT TCTCTGCTGT CAACTTCCCA TCTGGCTCAG CATAGGGTCA CTTTGCCATT 3120

ATGCAAATGG AGATAAAAGC AATTCTGGCT GTCCAGGAGC TAATCTGACC GTTCTATTGT 3180

GTGGATGACC ACATAAGAAG GCAATTTTAG TGTATTAATC ATAGATTATT ATAAACTATA 3240

AACTTAAGGG CAAGGAGTTT ATTACAATGT ATCTTTATTA AAACAAAAGG GTGTATAGTG 3300

TTCACAAACT GTGAAAATAG TGTAAGAACT GTACATTGTG AGCTCTGGTT ATTTTTCTCT 3360

TGTACCATAG AAAAATGTAT AAAAATTATC AAAAAGCTAA TGTGCAGGGA TATTGCCTTA 3420

TTTGTCTGTA AAAAATGGAG CTCAGTAACA TAACTGCTTC TTGGAGCTTT GGAATATTTT 3480

ATCCTGTATT CTTGTTT 3497

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 363 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

Met Gln Gly Lys Arg Lys Ala Leu Lys Leu Asn Phe Ala Asn Pro Pro
1 5 10 15

Phe Lys Ser Thr Ala Arg Phe Thr Leu Asn Pro Asn Pro Thr Gly Val
20 25 30

Gln Asn Pro His Ile Glu Arg Leu Arg Thr His Ser Ile Glu Ser Ser
35 40 45

Gly Lys Leu Lys Ile Ser Pro Glu Gln His Trp Asp Phe Thr Ala Glu
50 55 60

Asp Leu Lys Asp Leu Gly Glu Ile Gly Arg Gly Ala Tyr Gly Ser Val
65 70 75 80

Asn Lys Met Val His Lys Pro Ser Gly Gln Ile Met Ala Val Lys Arg
85 90 95

Ile Arg Ser Thr Val Asp Glu Lys Glu Gln Lys Gln Leu Leu Met Asp
100 105 110

Leu Asp Val Val Met Arg Ser Ser Asp Cys Pro Tyr Ile Val Gln Phe
115 120 125

Tyr Gly Ala Leu Phe Arg Glu Gly Asp Cys Trp Ile Cys Met Glu Leu
130 135 140

Met Ser Thr Ser Phe Asp Lys Phe Tyr Lys Tyr Val Tyr Ser Val Leu
145 150 155 160

Asp Asp Val Ile Pro Glu Glu Ile Leu Gly Lys Ile Thr Leu Ala Thr
165 170 175

Val Lys Ala Leu Asn His Leu Lys Glu Asn Leu Lys Ile Ile His Arg
180 185 190

Asp Ile Lys Pro Ser Asn Ile Leu Leu Asp Arg Ser Gly Asn Ile Lys
195 200 205

Leu Cys Asp Phe Gly Ile Ser Gly Gln Leu Val Asp Ser Ile Ala Lys
210 215 220

Thr Arg Asp Ala Gly Cys Arg Pro Tyr Met Ala Pro Glu Arg Ile Asp
225 230 235 240

Pro Ser Ala Ser Arg Gln Gly Tyr Asp Val Arg Ser Asp Val Trp Ser
245 250 255

Leu Gly Ile Thr Leu Tyr Glu Leu Ala Thr Gly Arg Phe Pro Tyr Pro
260 265 270

Lys Trp Asn Ser Val Phe Asp Gln Leu Thr Gln Val Val Lys Gly Asp
275 280 285

Pro Pro Gln Leu Ser Asn Ser Glu Glu Arg Glu Phe Ser Pro Ser Phe
290 295 300

Ile Asn Phe Val Asn Leu Cys Leu Thr Lys Asp Glu Ser Lys Arg Pro
305 310 315 320

Lys Tyr Lys Glu Leu Leu Lys His Pro Phe Ile Leu Met Tyr Glu Glu
325 330 335

Arg Ala Val Glu Val Ala Cys Tyr Val Cys Lys Ile Leu Asp Gln Met
340 345 350

Pro Ala Thr Pro Ser Ser Pro Met Tyr Val Asp
355 360

(2) INFORMATION FOR SEQ ID NO:7:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 3553 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:7:

CAACAATGGC GGCTCCGAGC CCGAGCGGTG GCGGCGGCAG CGGCACCCCC GGCCCCGTAG 60

GGTCCCCGGC GCCAGGCCAC CCGGCCGTCA GCAGCATGCA GGGTAAACGC AAAGCACTGA 120

AGTTGAATTT TGCAAATCCA CCTTTCAAAT CTACAGCAAG GTTTACTCTG AATCCCAATC 180

CTACAGGAGT TCAAAACCCA CACATAGAGA GACTGAGAAC ACACAGCATT GAGTCATCAG 240

GAAAACTGAA GATCTCCCCT GAACAACACT GGGATTTCAC TGCAGAGGAC TTGAAAGACC 300

TTGGAGAAAT TGGACGAGGA GCTTATGGTT CTGTCAACAA AATGGTCCAC AAACCAAGTG 360

GGCAAATAAT GGCAGTTAAA AGAATTCGGT CAACAGTGGA TGAAAAAGAA CAAAAACAAC 420

TTCTTATGGA TTTGGATGTA GTAATGCGGA GTAGTGATTG CCCATACATT GTTCAGTTTT 480

ATGGTGCACT CTTCAGAGAG GGTGACTGTT GGATCTGTAT GGAACTCATG TCTACCTCGT 540

TTGATAAGTT TTACAAATAT GTATATAGTG TATTAGATGA TGTTATTCCA GAAGAAATTT 600

TAGGCAAAAT CACTTTAGCA ACTGTGAAAG CACTAAACCA CTTAAAAGAA AACTTGAAAA 660

TTATTCACAG AGATATCAAA CCTTCCAATA TTCTTCTGGA CAGAAGTGGA AATATTAAGC 720

TCTGTGACTT CGGCATCAGT GGACAGCTTG TGGACTCTAT TGCCAAGACA AGAGATGCTG 780

GCTGTAGGCC ATACATGGCA CCTGAAAGAA TAGACCCAAG CGCATCACGA CAAGGATATG 840

ATGTCCGCTC TGATGTCTGG AGTTTGGGGA TCACATTGTA TGAGTTGGCC ACAGGCCGAT 900

TTCCTTATCC AAAGTGGAAT AGTGTATTTG ATCAACTAAC ACAAGTCGTG AAAGGAGATC 960

CTCCGCAGCT GAGTAATTCT GAGGAAAGGG AATTCTCCCC GAGTTTCATC AACTTTGTCA 1020

ACTTGTGCCT TACGAAGGAT GAATCCAAAA GGCCAAAGTA TAAAGAGCTT CTGAAACATC 1080

CCTTTATTTT GATGTATGAA GAACGTGCCG TTGAGGTCGC ATGCTATGTT TGTAAAATCC 1140

TGGATCAAAT GCCAGCTACT CCCAGCTCTC CCATGTATGT CGATTGATAT CGTGCTACAT 1200

CAGACTCTAG AAAAAAGGGC TGAGAGGAAG CAAGACGTAA AGAATTTTCA TCCCGTATCA 1260

CAGTGTTTTT ATTGCTCGCC CAGACACCAT GTGCAATAAG ATTGGTGTTC GTTTCCATCA 1320

TGTCTGTATA CTCCTGTCAC CTAGAACGTG CATCCTTGTA ATACCTGATT GATCACACAG 1380

TGTTAGTGCT GGTCAGAGAG ACCTCATCCT GCTCTTTTGT GATGAACATA TTCATGAAAT 1440

GTGGAAGTCA GTACGATCAA GTTGTTGACT GTGATTAGAT CACATCTTAA ATTCATTTCT 1500

AGACTCAAAA CCTGGAGATG CAGCTACTGG AATGGTGTTT TGTCAGACTT CCAAATCCTG 1560

GAAGGACACA GTGATGAATG TACTATATCT GAACATAGAA ACTCGGGCTT GAGTGAGAAG 1620

AGCTTGCACA GCCAACGAGA CACATTGCCT TCTGGAGCTG GGAGACAAAG GAGGAATTTA 1680

CTTTCTTCAC CAAGTGCAAT AGATTACTGA TGTGATATTC TGTTGCTTTA CAGTTACAGT 1740

TGATGTTTGG GGATCGATGT GCTCAGCCAA ATTTCCTGTT TGAAATATCA TGTTAAATTA 1800

GAATGAATTT ATCTTTACCA AAAACCATGT TGCGTTCAAA GAGGTGAACA TTAAAATATA 1860

GAGACAGGAC AGAATGTGTT CTTTTCTCCT CTACCAGTCC TATTTTTCAA TGGGAAGACT 1920

CAGGAGTCTG CCACTTGTCA AAGAAGGTGC TGATCCTAAG AATTTTTCAT TCTCAGAATT 1980

CGGTGTGCTG CCAACTTGAT GTTCCACCTG CCACAAACCA CCAGGACTGA AAGAAGAAAA 2040

CAGTACAGAA GGCAAAGTTT ACAGATGTTT TTAATTCTAG TATTTTATCT GGAACAACTT 2100

GTAGCAGCTA TATATTTCCC CTTGGTCCCA AGCCTGATAC TTTAGCCATC ATAACTCACT 2160

AACAGGGAGA AGTAGCTAGT AGCAATGTGC CTTGATTGAT TAGATAAAGA TTTCTAGTAG 2220

GCAGCAAAAG ACCAAATCTC AGTTGTTTGC TTCTTGCCAT CACTGGTCCA GGTCTTCAGT 2280

TTCCGAATCT CTTTCCCTTC CCCTGTGGTC TATTGTCGCT ATGTGACTTG CGCTTAATCC 2340

AATATTTTGC CTTTTTTCTA TATCAAAAAA CCTTTACAGT TAGCAGGGAT TTCCTTACC 2400

GAGGATTTTT AACCCCCAAT CTCTCATAAT CGCTAGTGTT TAAAAGGCTA AGAATAGTGG 2460

GGCCCAACCG ATGTGGTAGG TGATAAAGAG GCATCTTTTC TAGAGACACA TTGGACCAGA 2520

TGAGGATCCG AAACGGCAGC CTTTACGTTC ATCACCTGCT AGAACCTCTC GTAGTCCATC 2580

ACCATTTCTT GGCATTGGAA TTCTACTGGA AAAAAATACA AAAAGCAAAA CAAAACCCTC 2640

AGCACTGTTA CAAGAGGCCA TTTAAGTATC TTGTGCTTCT TCACTTACCC ATTAGCCAGG 2700

TTCTCATTAG GTTTTGCTTG GGCCTCCCTG GCACTGAACC TTAGGCTTTG TATGACAGTG 2760

AAGCAGCACT GTGAGTGGTT CAAGCACACT GGAATATAAA ACAGTCATGG CCTGAGATGC 2820

AGGTGATGCC ATTACAGAAC CAAATCGTGG CACGTATTGC TGTGTCTCCT CTCAGAGTGA 2880

CAGTCATAAA TACTGTCAAA CAATAAAGGG AGAATGGTGC TGTTTAAAGT CACATCCCTG 2940

TAAATTGCAG AATTCAAAAG TGATTATCTC TTTGATCTAC TTGCCTCATT TCCCTATCTT 3000

CTCCCCCACG GTATCCTAAA CTTTAGACTT CCCACTGTTC TGAAAGGAGA CATTGCTCTA 3060

TGTCTGCCTT CGACCACAGC AAGCCATCAT CCTCCATTGC TCCCGGGGAC TCAAGAGGAA 3120

TCTGTTTCTC TGCTGTCAAC TTCCCATCTG GCTCAGCATA GGGTCACTTT GCCATTATGC 3180

AAATGGAGAT AAAAGCAATT CTGGCTGTCC AGGAGCTAAT CTGACCGTTC TATTGTGTGG 3240

ATGACCACAT AAGAAGGCAA TTTTAGTGTA TTAATCATAG ATTATTATAA ACTATAAACT 3300

TAAGGGCAAG GAGTTTATTA CAATGTATCT TTATTAAAAC AAAAGGGTGT ATAGTGTTCA 3360

CAAACTGTGA AAATAGTGTA AGAACTGTAC ATTGTGAGCT CTGGTTATTT TTCTCTTGTA 3420

CCATAGAAAA ATGTATAAAA ATTATCAAAA AGCTAATGTG CAGGGATATT GCCTTATTTG 3480

TCTGTAAAAA ATGGAGCTCA GTAACATAAC TGCTTCTTGG AGCTTTGGAA TATTTTATCC 3540

TGTATTCTTG TTT 3553

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 393 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

Met Ala Ala Pro Ser Pro Ser Gly Gly Gly Gly Ser Gly Thr Pro Gly
1 5 10 15

Pro Val Gly Ser Pro Ala Pro Gly His Pro Ala Val Ser Ser Met Gln
20 25 30

Gly Lys Arg Lys Ala Leu Lys Leu Asn Phe Ala Asn Pro Pro Phe Lys
35 40 45

Ser Thr Ala Arg Phe Thr Leu Asn Pro Asn Pro Thr Gly Val Gln Asn
50 55 60

Pro His Ile Glu Arg Leu Arg Thr His Ser Ile Glu S r Ser Gly Lys
65 70 75 80

Leu Lys Ile Ser Pro Glu Gln His Trp Asp Phe Thr Ala Glu Asp Leu
85 90 95

Lys Asp Leu Gly Glu Ile Gly Arg Gly Ala Tyr Gly Ser Val Asn Lys
100 105 110

Met Val His Lys Pro Ser Gly Gln Ile Met Ala Val Lys Arg Ile Arg
115 120 125

Ser Thr Val Asp Glu Lys Glu Gln Lys Gln Leu Leu Met Asp Leu Asp
130 135 140

Val Val Met Arg Ser Ser Asp Cys Pro Tyr Ile Val Gln Phe Tyr Gly
145 150 155 160

Ala Leu Phe Arg Glu Gly Asp Cys Trp Ile Cys Met Glu Leu Met Ser
165 170 175

Thr Ser Phe Asp Lys Phe Tyr Lys Tyr Val Tyr Ser Val Leu Asp Asp
180 185 190

Val Ile Pro Glu Glu Ile Leu Gly Lys Ile Thr Leu Ala Thr Val Lys
195 200 205

Ala Leu Met His Leu Lys Glu Asn Leu Lys Ile Ile His Arg Asp Ile
210 215 220

Lys Pro Ser Asn Ile Leu Leu Asp Arg Ser Gly Met Ile Lys Leu Cys
225 230 235 240

Asp Phe Gly Ile Ser Gly Gln Leu Val Asp Ser Ile Ala Lys Thr Arg
245 250 255

Asp Ala Gly Cys Arg Pro Tyr Met Ala Pro Glu Arg Ile Asp Phe Ser
260 265 270

Ala Ser Arg Gln Gly Tyr Asp Val Arg Ser Asp Val Trp Ser Leu Gly
275 280 285

Ile Thr Leu Tyr Glu Leu Ala Thr Gly Arg Phe Pro Tyr Pro Lys Trp
290 295 300

Asn Ser Val Phe Asp Gln Leu Thr Gln Val Val Lys Gly Asp Pro Pro
305 310 315 320

Gln Leu Ser Asn Ser Glu Glu Arg Glu Phe Ser Pro Ser Phe Ile Asn
325 330 335

Phe Val Asn Leu Cys Leu Thr Lys Asp Glu Ser Lys Arg Pro Lys Tyr
340 345 350

Lys Glu Leu Leu Lys His Pro Phe Ile Leu Met Tyr Glu Glu Arg Ala
355 360 365

Val Glu Val Ala Cys Tyr Val Cys Lys Ile Leu Asp Gln Met Pro Ala
370 375 380

Thr Pro Ser Ser Pro Met Tyr Val Asp
385 390

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 3576 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

CTCCCAACAA TGGCGGCTCC GAGCCCGAGC GGCGGCGGCG GCTCCGGGGG CGGCAGCGGC 60

AGCGGCACCC CCGGCCCCGT AGGGTCCCCG GCGCCAGGCC ACCCGGCCGT CAGCAGCATG 120

CAGGGTAAAC GCAAAGCACT GAAGTTGAAT TTTGCAAATC CACCTTTCAA ATCTACAGCA 180

AGGTTTACTC TGAATCCCAA TCCTACAGGA GTTCAAAACC CACACATAGA GAGACTGAGA 240

ACACACAGCA TTGAGTCATC AGGAAAACTG AAGATCTCCC CTGAACAACA CTGGGATTTC 300

ACTGCAGAGG ACTTGAAAGA CCTTGGAGAA ATTGGACGAG GAGCTTATGG TTCTGTCAAC 360

AAAATGGTCC ACAAACCAAG TGGGCAAATA ATGGCAGTTA AAAGAATTCG GTCAACAGTG 420

GATGAAAAAG AACAAAAACA ACTTCTTATG GATTTGGATG TAGTAATGCG GAGTAGTGAT 480

TGCCCATACA TTGTTCAGTT TTATGGTGCA CTCTTCAGAG AGGGTGACTG TTGGATCTGT 540

ATGGAACTCA TGTCTACCTC GTTTGATAAG TTTTACAAAT ATGTATATAG TGTATTAGAT 600

GATGTTATTC CAGAAGAAAT TTTAGGCAAA ATCACTTTAG CAACTGTGAA AGCACTAAAC 660

CACTTAAAAG AAAACTTGAA AATTATTCAC AGAGATATCA AACCTTCCAA TATTCTTCTG 720

GACAGAAGTG GAAATATTAA GCTCTGTGAC TTCGGCATCA GTGGACAGCT TGTGGACTCT 780

ATTGCCAAGA CAAGAGATGC TGGCTGTAGG CCATACATGG CACCTGAAAG AATAGACCCA 840

AGCGCATCAC GACAAGGATA TGATGTCCGC TCTGATGTCT GGAGTTTGGG GATCACATTG 900

TATGAGTTGG CCACAGGCCG ATTTCCTTAT CCAAAGTGGA ATAGTGTATT TGATCAACTA 960

ACACAAGTCG TGAAAGGAGA TCCTCCGCAG CTGAGTAATT CTGAGGAAAG GGAATTCTCC 1020

CCGAGTTTCA TCAACTTTGT CAACTTGTGC CTTACGAAGG ATGAATCCAA AAGGCCAAAG 1080

TATAAAGAGC TTCTGAAACA TCCCTTTATT TTGATGTATG AAGAACGTGC CGTTGAGGTC 1140

GCATGCTATG TTTGTAAAAT CCTGGATCAA ATGCCAGCTA CTCCCAGCTC TCCCATGTAT 1200

GTCGATTGAT ATCGCTGCTA CATCAGACTC TAGAAAAAAG GGCTGAGAGG AAGCAAGACG 1260

TAAAGAATTT TCATCCCGTA TCACAGTGTT TTTATTGCTC GCCCAGACAC CATGTGCAAT 1320

AAGATTGGTG TTCGTTTCCA TCATGTCTGT ATACTCCTGT CACCTAGAAC GTGCATCCTT 1380

GTAATACCTG ATTGATCACA CAGTGTTAGT GCTGGTCAGA GAGACCTCAT CCTGCTCTTT 1440

TGTGATGAAC ATATTCATGA AATGTGGAAG TCAGTACGAT CAAGTTGTTG ACTGTGATTA 1500

GATCACATCT TAAATTCATT TCTAGACTCA AAACCTGGAG ATGCAGCTAC TGGAATGGTG 1560

TTTTGTCAGA CTTCCAAATC CTGGAAGGAC ACAGTGATGA ATGTACTATA TCTGAACATA 1620

GAAACTCGGG CTTGAGTGAG AAGAGCTTGC ACAGCCAACG AGACACATTG CCTTCTGGAG 1680

CTGGGAGACA AAGGAGGAAT TTACTTTCTT CACCAAGTGC AATAGATTAC TGATGTGATA 1740

TTCTGTTGCT TTACAGTTAC AGTTGATGTT TGGGGATCGA TGTGCTCAGC CAAATTTCCT 1800

GTTTGAAATA TCATGTTAAA TTAGAATGAA TTTATCTTTA CCAAAAACCA TGTTGCGTTC 1860

AAAGAGGTGA ACATTAAAAT ATAGAGACAG GACAGAATGT GTTCTTTTCT CCTCTACCAG 1920

TCCTATTTTT CAATGGGAAG ACTCAGGAGT CTGCCACTTG TCAAAGAAGG TGCTGATCCT 1980

AAGAATTTTT CATTCTCAGA ATTCGGTGTG CTGCCAACTT GATGTTCCAC CTGCCACAAA 2040

CCACCAGGAC TGAAAGAAGA AAACAGTACA GAAGGCAAAG TTTACAGATG TTTTTAATTC 2100

TAGTATTTTA TCTGGAACAA CTTGTAGCAG CTATATATTT CCCCTTGGTC CCAAGCCTGA 2160

TACTTTAGCC ATCATAACTC ACTAACAGGG AGAAGTAGCT AGTAGCAATG TGCCTTGATT 2220

GATTAGATAA AGATTTCTAG TAGGCAGCAA AAGACCAAAT CTCAGTTGTT TGCTTCTTGC 2280

CATCACTGGT CCAGGTCTTC AGTTTCCGAA TCTCTTTCCC TTCCCCTGTG GTCTATTGTC 2340

GCTATGTGAC TTGCGCTTAA TCCAATATTT TGCCTTTTTT CTATATCAAA AAACCTTTAC 2400

AGTTAGCAGG GATGTTCCTT ACCGAGGATT TTTAACCCCC AATCTCTCAT AATCGCTAGT 2460

GTTTAAAAGG CTAAGAATAG TGGGGCCCAA CCGATGTGGT AGGTGATAAA GAGGCATCTT 2520

TTCTAGAGAC ACATTGGACC AGATGAGGAT CCGAAACGGC AGCCTTTACG TTCATCACCT 2580

GCTAGAACCT CTCGTAGTCC ATCACCATTT CTTGGCATTG GAATTCTACT GGAAAAAAAT 2640

ACAAAAAGCA AAACAAAACC CTCAGCACTG TTACAAGAGG CCATTTAAGT ATCTTGTGCT 2700

TCTTCACTTA CCCATTAGCC AGGTTCTCAT TAGGTTTTGC TTGGGCCTCC CTGGCACTGA 2760

ACCTTAGGCT TTGTATGACA GTGAAGCAGC ACTGTGAGTG GTTCAAGCAC ACTGGAATAT 2820

AAAACAGTCA TGGCCTGAGA TGCAGGTGAT GCCATTACAG AACCAAATCG TGGCACGTAT 2880

TGCTGTGTCT CCTCTCAGAG TGACAGTCAT AAATACTGTC AAACAATAAA GGGAGAATGG 2940

TGCTGTTTAA AGTCACATCC CTGTAAATTG CAGAATTCAA AAGTGATTAT CTCTTTGATC 3000

TACTTGCCTC ATTTCCCTAT CTTCTCCCCC ACGGTATCCT AAACTTTAGA CTTCCCACTG 3060

TTCTGAAAGG AGACATTGCT CTATGTCTGC CTTCGACCAC AGCAAGCCAT CATCCTCCAT 3120

TGCTCCCGGG GACTCAAGAG GAATCTGTTT CTCTGCTGTC AACTTCCCAT CTGGCTCAGC 3180

ATAGGGTCAC TTTGCCATTA TGCAAATGGA GATAAAAGCA ATTCTGGCTG TCCAGGAGCT 3240

AATCTGACCG TTCTATTGTG TGGATGACCA CATAAGAAGG CAATTTTAGT GTATTAATCA 3300

TAGATTATTA TAAACTATAA ACTTAAGGGC AAGGAGTTTA TTACAATGTA TCTTTATTAA 3360

AACAAAAGGG TGTATAGTGT TCACAAACTG TGAAAATAGT GTAAGAACTG TACATTGTGA 3420

GCTCTGGTTA TTTTTCTCTT GTACCATAGA AAAATGTATA AAAATTATCA AAAAGCTAAT 3480

GTGCAGGGAT ATTGCCTTAT TTGTCTGTAA AAAATGGAGC TCAGTAACAT AACTGCTTCT 3540

TGGAGCTTTG AATATTTTA TCCTGTATTC TTGTTT 3576

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 399 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

Met Ala Ala Pro Ser Pro Ser Gly Gly Gly Gly Ser Gly Gly Gly Ser
1 5 10 15

Gly Ser Gly Thr Pro Gly Pro Val Gly Ser Pro Ala Pro Gly His Pro
20 25 30

Ala Val Ser Ser Met Gln Gly Lys Arg Lys Ala Leu Lys Leu Asn Phe
35 40 45

Ala Asn Pro Pro Phe Lys Ser Thr Ala Arg Phe Thr Leu Asn Pro Asn
50 55 60

Pro Thr Gly Val Gln Asn Pro His Ile Glu Arg Leu Arg Thr His Ser
65 70 75 80

Ile Glu Ser Ser Gly Lys Leu Lys Ile Ser Pro Glu Gln His Trp Asp
85 90 95

Phe Thr Ala Glu Asp Leu Lys Asp Leu Gly Glu Ile Gly Arg Gly Ala
100 105 110

Tyr Gly Ser Val Asn Lys Met Val His Lys Pro Ser Gly Gln Ile Met
115 120 125

Ala Val Lys Arg Ile Arg Ser Thr Val Asp Glu Lys Glu Gln Lys Gln
130 135 140

Leu Leu Met Asp Leu Asp Val Val Met Arg Ser Ser Asp Cys Pro Tyr
145 150 155 160

Ile Val Gln Phe Tyr Gly Ala Leu Phe Arg Glu Gly Asp Cys Trp Ile
165 170 175

Cys Met Glu Leu Met Ser Thr Ser Phe Asp Lys Phe Tyr Lys Tyr Val
180 185 190

Tyr Ser Val Leu Asp Asp Val Ile Pro Glu Glu Ile Leu Gly Lys Ile
195 200 205

Thr Leu Ala Thr Val Lys Ala Leu Asn His Leu Lys Glu Asn Leu Lys
210 215 220

Ile Ile His Arg Asp Ile Lys Pro Ser Asn Ile Leu Leu Asp Arg Ser
225 230 235 240

Gly Asn Ile Lys Leu Cys Asp Phe Gly Ile Ser Gly Gln Leu Val Asp
245 250 255

Ser Ile Ala Lys Thr Arg Asp Ala Gly Cys Arg Pro Tyr Met Ala Pro
260 265 270

Glu Arg Ile Asp Pro Ser Ala Ser Arg Gln Gly Tyr Asp Val Arg Ser
275 280 285

Asp Val Trp Ser Leu Gly Ile Thr Leu Tyr Glu Leu Ala Thr Gly Arg
290 295 300

Phe Pro Tyr Pro Lys Trp Asn Ser Val Phe Asp Gln Leu Thr Gln Val
305 310 315 320

Val Lys Gly Asp Pro Pro Gln Leu Ser Asn Ser Glu Glu Arg Glu Phe
325 330 335

Ser Pro Ser Phe Ile Asn Phe Val Asn Leu Cys Leu Thr Lys Asp Glu
340 345 350

Ser Lys Arg Pro Lys Tyr Lys Glu Leu Leu Lys His Pro Phe Ile Leu
355 360 365

Met Tyr Glu Glu Arg Ala Val Glu Val Ala Cys Tyr Val Cys Lys Ile
370 375 380

Leu Asp Gln Met Pro Ala Thr Pro Ser Ser Pro Met Tyr Val Asp
385 390 395

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 393 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

Met Pro Lys Lys Lys Pro Thr Pro Ile Gln Leu Asn Pro Ala Pro Asp
1 5 10 15

Gly Ser Ala Val Asn Gly Thr Ser Ser Ala Glu Thr Asn Leu Glu Ala
20 25 30

Leu Gln Lys Lys Leu Glu Glu Leu Glu Leu Asp Glu Gln Gln Arg Lys
35 40 45

Arg Leu Glu Ala Phe Leu Thr Gln Lys Gln Lys Val Gly Glu Leu Lys
50 55 60

Asp Asp Asp Phe Glu Lys Ile Ser Glu Leu Gly Ala Gly Asn Gly Gly
65 70 75 80

Val Val Phe Lys Val Ser His Lys Pro Ser Gly Leu Val Met Ala Arg
85 90 95

Lys Leu Ile His Leu Glu Ile Lys Pro Ala Ile Arg Asn Gln Ile Ile
100 105 110

Arg Glu Leu Gln Val Leu His Glu Cys Asn Ser Pro Tyr Ile Val Gly
115 120 125

Phe Tyr Gly Ala Phe Tyr Ser Asp Gly Glu Ile Ser Ile Cys Met Glu
130 135 140

His Met Asp Gly Gly Ser Leu Asp Gln Val Leu Lys Lys Ala Gly Arg
145 150 155 160

Ile Pro Glu Gln Ile Leu Gly Lys Val Ser Ile Ala Val Ile Lys Gly
165 170 175

Leu Thr Tyr Leu Arg Glu Lys His Lys Ile Met His Arg Asp Val Lys
180 185 190

Pro Ser Asn Ile Leu Val Asn Ser Arg Gly Glu Ile Lys Leu Cys Asp
195 200 205

Phe Gly Val Ser Gly Gln Leu Ile Asp Ser Met Ala Asn Ser Phe Val
210 215 220

Gly Thr Arg Ser Tyr Met Ser Pro Glu Arg Leu Gln Gly Thr His Tyr
225 230 235 240

Ser Val Gln Ser Asp Ile Trp Ser Met Gly Leu Ser Leu Val Glu Met
245 250 255

Ala Val Gly Arg Tyr Pro Ile Pro Pro Pro Asp Ala Lys Glu Leu Glu
260 265 270

Leu Met Phe Gly Cys Gln Val Glu Gly Asp Ala Ala Glu Thr Pro Pro
275 280 285

Arg Pro Arg Thr Pro Gly Arg Pro Leu Ser Ser Tyr Gly Met Asp Ser
290 295 300

Arg Pro Pro Met Ala Ile Phe Glu Leu Leu Asp Tyr Ile Val Asn Glu
305 310 315 320

Pro Pro Pro Lys Leu Pro Ser Gly Val Phe Ser Leu Glu Phe Gln Asp
325 330 335

Phe Val Asn Lys Cys Leu Ile Lys Asn Pro Ala Glu Arg Ala Asp Leu
340 345 350

Lys Gln Leu Met Val His Ala Phe Ile Lys Arg Ser Asp Ala Glu Glu
355 360 365

Val Asp Phe Ala Gly Trp Leu Cys Ser Thr Ile Gly Leu Asn Gln Pro
370 375 380

Ser Thr Pro Thr His Ala Ala Gly Val
385 390

(2) INFORMATION FOR SEQ ID NO:12:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 400 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Met Leu Ala Arg Arg Lys Pro Val Leu Pro Ala Leu Thr Ile Asn Pro
1 5 10 15

Thr Ile Ala Glu Gly Pro Ser Pro Thr Ser Glu Gly Ala Ser Glu Ala
20 25 30

Asn Leu Val Asp Leu Gln Lys Lys Leu Glu Glu Leu Glu Leu Asp Glu
35 40 45

Gln Gln Lys Lys Arg Leu Glu Ala Phe Leu Thr Gln Lys Ala Lys Val
50 55 60

Ser Glu Leu Lys Asp Asp Asp Phe Glu Arg Ile Ser Glu Leu Gly Ala
65 70 75 80

Gly Asn Gly Gly Val Val Thr Lys Val Gln His Arg Pro Ser Gly Leu
85 90 95

Ile Met Ala Arg Lys Leu Ile His Leu Glu Ile Lys Pro Ala Ile Arg
100 105 110

Asn Gln Ile Ile Arg Glu Leu Gln Val Leu His Glu Cys Asn Ser Pro
115 120 125

Tyr Ile Val Gly Phe Tyr Gly Ala Phe Tyr Ser Asp Gly Glu Ile Ser
130 135 140

Ile Cys Met Glu His Met Asp Gly Gly Ser Leu Asp Gln Val Leu Lys
145 150 155 160

Glu Ala Lys Arg Ile Pro Glu Glu Ile Leu Gly Lys Val Ser Ile Ala
165 170 175

Val Leu Arg Gly Leu Ala Tyr Leu Arg Glu Lys His Gln Ile Met His
180 185 190

Arg Asp Val Lys Pro Ser Asn Ile Leu Val Asn Ser Arg Gly Glu Ile
195 200 205

Lys Leu Cys Asp Phe Gly Val Ser Gly Gln Leu Ile Asp Ser Met Ala
210 215 220

Asn Ser Phe Val Gly Thr Arg Ser Tyr Met Ala Pro Glu Arg Leu Gln
225 230 235 240

Gly Thr His Tyr Ser Val Gln Ser Asp Ile Trp Ser Met Gly Leu Ser
245 250 255

Leu Val Glu Leu Ala Val Gly Arg Tyr Pro Ile Pro Pro Pro Asp Ala
260 265 270

Lys Glu Leu Glu Ala Ile Phe Gly Arg Pro Val Val Asp Gly Glu Glu
275 280 285

Gly Glu Pro His Ser Ile Ser Pro Arg Pro Arg Pro Pro Gly Arg Pro
290 295 300

Val Ser Gly His Gly Met Asp Ser Arg Pro Ala Met Ala Ile Phe Glu
305 310 315 320

Leu Leu Asp Tyr Ile Val Asn Glu Pro Pro Pro Lys Leu Pro Asn Gly
325 330 335

Val Phe Thr Pro Asp Phe Gln Glu Phe Val Asn Lys Cys Leu Ile Lys
340 345 350

Asn Pro Ala Glu Arg Ala Asp Leu Lys Met Leu Thr Asn His Thr Phe
355 360 365

Ile Lys Arg Ser Glu Val Glu Glu Val Asp Phe Ala Gly Trp Leu Cys
370 375 380

Lys Thr Leu Arg Leu Asn Gln Pro Gly Thr Pro Thr Arg Thr Ala Val
385 390 395 400

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 668 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS: not relevant
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

Met Glu Asp Lys Phe Ala Asn Leu Ser Leu His Glu Lys Thr Gly Lys
1 5 10 15

Ser Ser Ile Gln Leu Asn Glu Gln Thr Gly Ser Asp Asn Gly Ser Ala
20 25 30

Val Lys Arg Thr Ser Ser Thr Ser Ser His Tyr Asn Asn Ile Asn Ala
35 40 45

Asp Leu His Ala Arg Val Lys Ala Phe Gln Glu Gln Arg Ala Leu Lys
50 55 60

Arg Ser Ala Ser Val Gly Ser Asn Gln Ser Glu Gln Asp Lys Gly Ser
65 70 75 80

Ser Gln Ser Pro Lys His Ile Gln Gln Ile Val Asn Lys Pro Leu Pro
85 90 95

Pro Leu Pro Val Ala Gly Ser Ser Lys Val Ser Gln Arg Met Ser Ser
100 105 110

Gln Val Val Gln Ala Ser Ser Lys Ser Thr Leu Lys Asn Val Leu Asp
115 120 125

Asn Gln Glu Thr Gln Asn Ile Thr Asp Val Asn Ile Asn Ile Asp Thr
130 135 140

Thr Lys Ile Thr Ala Thr Thr Ile Gly Val Asn Ile Gly Leu Pro Ala
145 150 155 160

Thr Asp Ile Thr Pro Ser Val Ser Asn Thr Ala Ser Ala Thr His Lys
165 170 175

Ala Gln Leu Leu Asn Pro Asn Arg Arg Ala Pro Arg Arg Pro Leu Ser
180 185 190

Thr Gln His Pro Thr Arg Pro Asn Val Ala Pro His Lys Ala Pro Ala
195 200 205

Ile Ile Asn Thr Pro Lys Gln Ser Leu Ser Ala Arg Arg Gly Leu Lys
210 215 220

Leu Pro Pro Gly Gly Met Ser Leu Lys Met Pro Thr Lys Thr Ala Gln
225 230 235 240

Gln Pro Gln Gln Phe Ala Pro Ser Pro Ser Asn Lys Lys His Ile Glu
245 250 255

Thr Leu Ser Asn Ser Lys Val Val Glu Gly Lys Arg Ser Asn Pro Gly
260 265 270

Ser Leu Ile Asn Gly Val Gln Ser Thr Ser Thr Ser Ser Ser Thr Glu
275 280 285

Gly Pro His Asp Thr Val Gly Thr Thr Pro Arg Thr Gly Asn Ser Asn
290 295 300

Asn Ser Ser Asn Ser Gly Ser Ser Gly Gly Gly Gly Leu Phe Ala Asn
305 310 315 320

Phe Ser Lys Tyr Val Asp Ile Lys Ser Gly Ser Leu Asn Phe Ala Gly
325 330 335

Lys Leu Ser Leu Ser Ser Lys Gly Ile Asp Phe Ser Asn Gly Ser Ser
340 345 350

Ser Arg Ile Thr Leu Asp Glu Leu Glu Phe Leu Asp Glu Leu Gly His
355 360 365

Gly Asn Tyr Gly Asn Val Ser Lys Val Leu His Lys Pro Thr Asn Val
370 375 380

Ile Met Ala Thr Lys Glu Val Arg Leu Glu Leu Asp Glu Ala Lys Phe
385 390 395 400

Arg Gln Ile Leu Met Glu Leu Glu Val Leu His Lys Cys Asn Ser Pro
405 410 415

Tyr Ile Val Asp Phe Tyr Gly Ala Phe Phe Ile Glu Gly Ala Val Tyr
420 425 430

Met Cys Met Glu Tyr Met Asp Gly Gly Ser Leu Asp Lys Ile Tyr Asp
435 440 445

Glu Ser Ser Glu Ile Gly Gly Ile Asp Glu Pro Gln Leu Ala Phe Ile
450 455 460

Ala Asn Ala Val Ile His Gly Leu Lys Glu Leu Lys Glu Gln His Asn
465 470 475 480

Ile Ile His Arg Asp Val Lys Pro Thr Asn Ile Leu Cys Ser Ala Asn
485 490 495

Gln Gly Thr Val Lys Leu Cys Asp Phe Gly Val Ser Gly Asn Leu Val
500 505 510

Ala Ser Leu Ala Lys Thr Asn Ile Gly Cys Gln Ser Tyr Met Ala Pro
515 520 525

Glu Arg Ile Lys Ser Leu Asn Pro Asp Arg Ala Thr Tyr Thr Val Gln
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Ser Asp Ile Trp Ser Leu Gly Leu Ser Ile Leu Glu Met Ala Leu Gly
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Arg Tyr Pro Tyr Pro Pro Glu Thr Tyr Asp Asn Ile Phe Ser Gln Leu
565 570 575

Ser Ala Ile Val Asp Gly Pro Pro Pro Arg Leu Pro Ser Asp Lys Phe
580 585 590

Ser Ser Asp Ala Gln Asp Phe Val Ser Leu Cys Leu Gln Lys Ile Pro
595 600 605

Glu Arg Arg Pro Thr Tyr Ala Ala Leu Thr Glu His Pro Trp Leu Val
610 615 620

Lys Tyr Arg Asn Gln Asp Val His Met Ser Glu Tyr Ile Thr Glu Arg
625 630 635 640

Leu Glu Arg Arg Asn Lys Ile Leu Arg Glu Arg Gly Glu Asn Gly Leu
645 650 655

Ser Lys Asn Val Pro Ala Leu His Met Gly Gly Leu
660 665

(2) INFORMATION FOR SEQ ID NO:14:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 23 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

TTYTAYGGNG CNTTYTTYAT HGA 23

(2) INFORMATION FOR SEQ ID NO:15:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 20 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

ATBCTYTCNG GNGCCATKTA 20

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:
(A) LENGTH: 17 base pairs
(B) TYPE: nucleic acid
(C) STRANDEDNESS: single
(D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

ASTYRYSASA SASASYS 17

CLAIMS

What is claimed is:

1. A substantially pure human mitogen-activated protein kinase kinase (MKK) polypeptide having serine, threonine, and tyrosine kinase activity, and phosphorylating human mitogen-activated protein (MAP) kinase p38.

2. A polypeptide of claim 1 comprising the amino acid sequence of SEQ ID NO:2.

3. An isolated and purified polynucleotide sequence encoding a polypeptide of claim 2.

4. An isolated and purified polynucleotide sequence of claim 3 consisting of the sequence of SEQ ID NO:1 or degenerate variants thereof, or a polynucleotide sequence fully complementary to the sequence of SEQ ID NO:1 or degenerate variants thereof.

5. An isolated and purified polynucleotide sequence of claim 3 consisting of a polynucleotide sequence that hybridizes under stringent hybridization conditions to the sequence of SEQ ID NO:1.

6. A polypeptide of claim 1 comprising the amino acid sequence of SEQ ID NO:4.

7. An isolated and purified polynucleotide sequence encoding a polypeptide of claim 6.

8. An isolated and purified polynucleotide sequence of claim 3 consisting of the sequence of SEQ ID NO:3 or degenerate variants thereof, or a polynucleotide

sequence fully complementary to the sequence of SEQ ID NO:3 or degenerate variants thereof.

9. An isolated and purified polynucleotide sequence of claim 7 consisting of a polynucleotide sequence that hybridizes under stringent hybridization conditions to the sequence of SEQ ID NO:3.

10. A polypeptide of claim 1, further characterized in that said polypeptide phosphorylates human mitogen-activated protein (MAP) kinase JNK.

11. A polypeptide of claim 10 comprising the amino acid sequence of SEQ ID NO:6.

12. An isolated and purified polynucleotide sequence encoding a polypeptide of claim 11.

13. An isolated and purified polynucleotide sequence of claim 12 consisting of the sequence of SEQ ID NO:5 or degenerate variants thereof, or a polynucleotide sequence fully complementary to the sequence of SEQ ID NO:5 or degenerate variants thereof.

14. An isolated and purified polynucleotide sequence of claim 12 consisting of a polynucleotide sequence that hybridizes under stringent hybridization conditions to the sequence of SEQ ID NO:5.

15. A polypeptide of claim 10 comprising an amino acid sequence of SEQ ID NO:8.

16. An isolated and purified polynucleotide sequence encoding a polypeptide of claim 15.

17. An isolated and purified polynucleotide sequence of claim 16 consisting of the sequence of SEQ ID NO:7 or degenerate variants thereof, or a polynucleotide sequence fully complementary to the sequence of SEQ ID NO:7 or degenerate variants thereof.

18. An isolated and purified polynucleotide sequence of claim 16 consisting of a polynucleotide sequence that hybridizes under stringent hybridization conditions to the sequence of SEQ ID NO:7.

19. A polypeptide of claim 10 comprising the amino acid sequence of SEQ ID NO:10.

20. An isolated and purified polynucleotide sequence encoding a polypeptide of claim 19.

21. An isolated and purified polynucleotide sequence of claim 20 consisting of the sequence of SEQ ID NO:9 or degenerate variants thereof, or a polynucleotide sequence fully complementary to the sequence of SEQ ID NO:9 or degenerate variants thereof.

22. A recombinant expression vector comprising a polynucleotide sequence of any one of claims 3, 7, 12, 16, or 20.

23. A recombinant host cell comprising a polynucleotide sequence of any one of claims 3, 7, 12, 16, or 20.

24. A purified antibody which binds specifically to a polypeptide of any one of claims 1, 2, 6, 10, 11, 15, or 19.

25. A method of measuring the activity of a mitogen-activated protein kinase kinase (MKK) in a biological test sample, said method comprising:

a) incubating said test sample with an MKK substrate for the MKK polypeptide of claim 1 and labeled phosphate under conditions sufficient to allow phosphorylation of said substrate, and

b) determining the rate of incorporation of labeled phosphate into said substrate, wherein said rate of incorporation is a measure of MKK activity.

26. A method of claim 25, wherein said MKK substrate is selected from the group consisting of p38 and JNK MAP kinases, activating transcription factor-2 (ATF2), ATFa, cAMP response element binding protein (CRE-BPa), and c-Jun.

27. A method of claim 25, wherein said biological test sample is fluid, cells, or tissue obtained from a mammal.

28. A method for measuring the synthesis of MKK in a biological test sample, comprising the steps of:

a) fractionating proteins present in said sample by gel electrophoresis;

b) transferring the proteins onto a membrane; and

c) probing the proteins with a labeled antibody specific to a MKK polypeptide of claim 1, wherein the level of MKK synthesis is determined by the amount of bound labeled antibody.

29. A method for measuring the level of expression of MKK in a test sample, comprising the steps of:

a) isolating polyadenylated RNA from the test sample;

b) incubating polyadenylated RNA with a polynucleotide probe specific for a MKK polypeptide of claim 1;

c) determining the amount of said probe hybridized said polyadenylated RNA, wherein the level of expression of MKK is directly related to the amount of MKK probe hybridized to said RNA.

30. A method for identifying a reagent which modulates MKK synthesis, said method comprising:

a) using the method of claim 28;

b) comparing the effect of said reagent on MKK synthesis relative to a control, wherein a reagent able to modulate MKK synthesis is identified.

31. A method of claim 30 wherein said MKK substrate is one or more of p38, JNK, ATF2, ATFa, CRE-BPa, and c-Jun.

32. A method of claim 30 wherein said modulation is inhibition of MKK synthesis.

33. A substantially pure human mitogen-activated protein kinase kinase (MKK) polypeptide of any one of claims 1, 2, 6, 10, 11, 15, or 19 for use in treating an MKK-mediated disorder.

34. The polypeptide of claim 33, wherein said MKK-mediated disorder is selected from the group consisting of ischemic heart disease, kidney failure, oxidative liver damage, respiratory distress syndrome, heat and radiation burns, septic shock, rheumatoid

arthritis, autoimmune disorders, and inflammatory diseases.

35. The use of a polypeptide of claim 33 for the manufacture of a medicament for the treatment of an MKK-mediated disorder.

36. A kit useful for the detection of MKK, said kit comprising a buffer and a reagent which binds to a MKK polypeptide of any one of claims 1, 2, 6, 10, 11, 15, or 19, wherein a sample to be tested is mixed with said buffer and said reagent, and wherein said reagent is labeled.

37. A kit of claim 36, wherein said reagent is an antibody that specifically binds MKK.

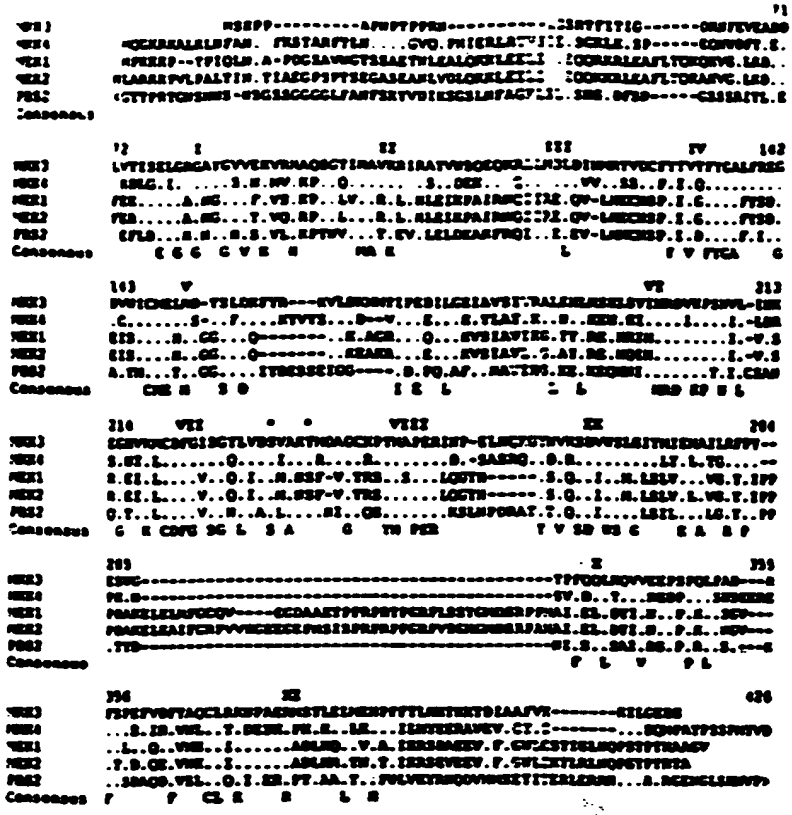
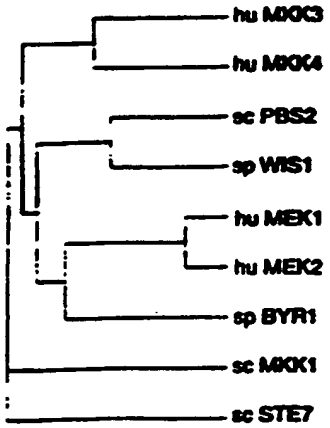


FIG. 1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hu MKK4
sc PBS2
sp WIS1
hu MEK1
hu MEK2
sp BYR1
sc MKK1
sc STE7

FIG. 2

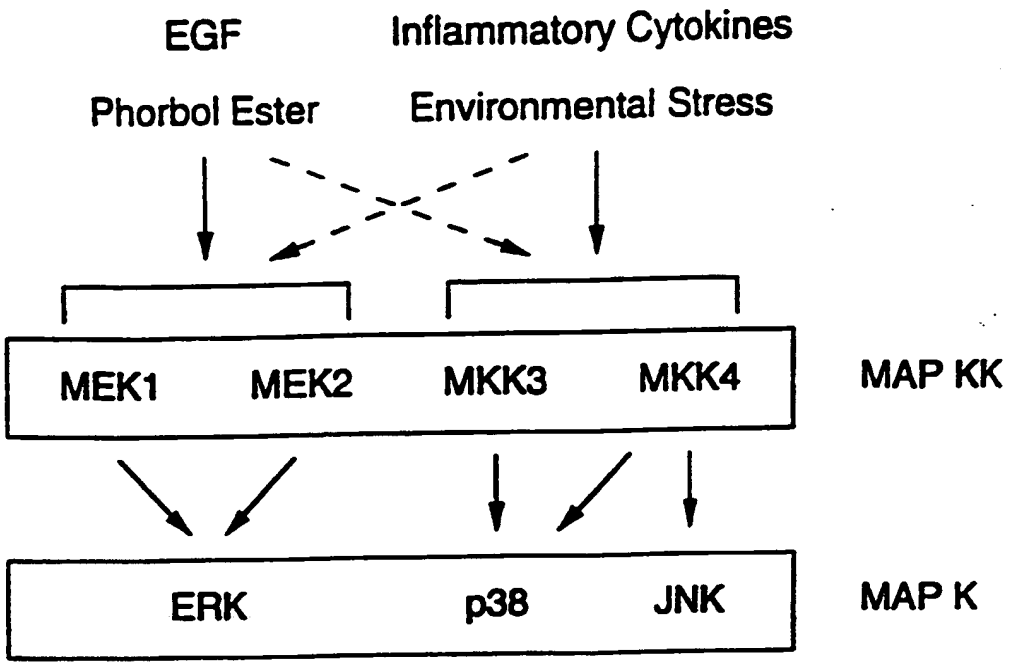
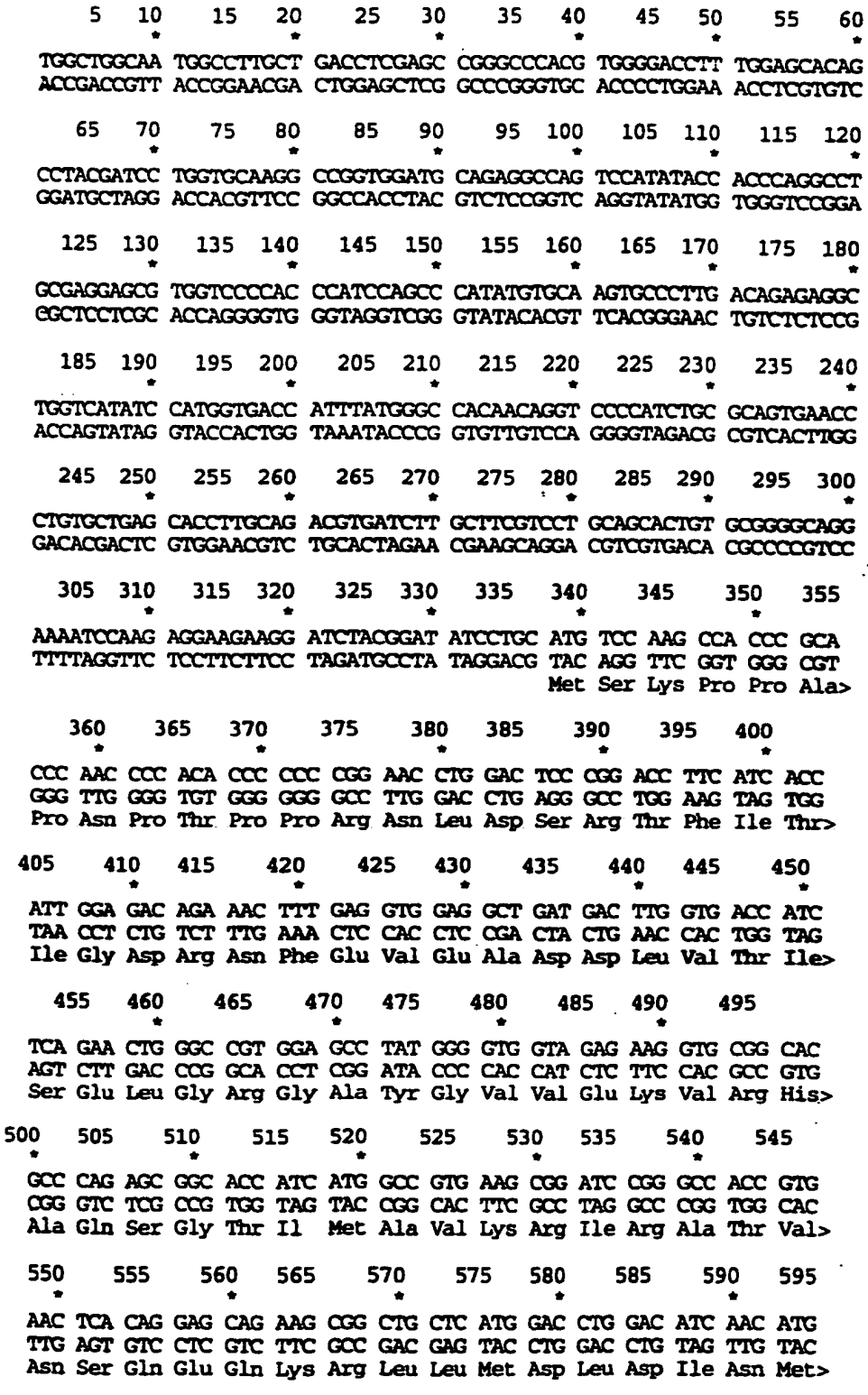

EGF
Inflammatory Cytokines
Phorbol Ester
Environmental Stress
MEK1
MEK2
MKK3
MKK4
MAP KK
ERK
p38
JNK
MAP K

FIG. 3

FIG. 4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TGGCTGGCAA TGGCCTTGCT GACCTCGAGC CGGGCCCACG TGGGGACCTT TGGAGCACAG
ACCGACCGTT ACCGGAACGA CTGGAGCTCG GCCCGGGTGC ACCCCTGGAA ACCTCGTGTC
65 70 75 80 85 90 95 100 105 110 115 120
CCTACGATCC TGGTGCAAGG CCGGTGGATG CAGAGGCCAG TCCATATACC ACCCAGGCCT
GGATGCTAGG ACCACGTTCC GGCCACCTAC GTCTCCGGTC AGGTATATGG TGGGTCCGGA
125 130 135 140 145 150 155 160 165 170 175 180
GCGAGGAGCG TGGTCCCCAC CCATCCAGCC CATATGTGCA AGTGCCCTTG ACAGAGAGGC
CGCTCCTCGC ACCAGGGGTG GGTAGGTCGG GTATACACGT TCACGGGAAC TGTCTCTCCG
185 190 195 200 205 210 215 220 225 230 235 240
TGGTCATATC CATGGTGACC ATTTATGGGC CACAACAGGT CCCCATCTGC GCAGTGAACC
ACCAGTATAG GTACCACTGG TAAATACCCG GTGTTGTCCA GGGGTAGACG CGTCACTTGG
245 250 255 260 265 270 275 280 285 290 295 300
CTGTGCTGAG CACCTTGCAG ACGTGATCTT GCTTCGTCCT GCAGCACTGT GCGGGGCAGG
GACACGACTC GTGGAACGTC TGCACTAGAA CGAAGCAGGA CGTCGTGACA CGCCCCGTCC
305 310 315 320 325 330 335 340 345 350 355
AAAATCCAAG AGGAAGAAGG ATCTACGGAT ATCCTGC ATG TCC AAG CCA CCC GCA
TTTTAGGTTC TCCTTCTTCC TAGATGCCTA TAGGACG TAC AGG TTC GGT GGG CGT
Met Ser Lys Pro Pro Ala>
360 365 370 375 380 385 390 395 400
CCC AAC CCC ACA CCC CCC CGG AAC CTG GAC TCC CGG ACC TTC ATC ACC
GGG TTG GGG TGT GGG GGG GCC TTG GAC CTG AGG GCC TGG AAG TAG TGG
Pro Asn Pro Thr Pro Pro Arg Asn Leu Asp Ser Arg Thr Phe Ile Thr>
405 410 415 420 425 430 435 440 445 450
ATT GGA GAC AGA AAC TTT GAG GTG GAG GCT GAT GAC TTG GTG ACC ATC
TAA CCT CTG TCT TTG AAA CTC CAC CTC CGA CTA CTG AAC CAC TGG TAG
Ile Gly Asp Arg Asn Phe Glu Val Glu Ala Asp Asp Leu Val Thr Ile>
455 460 465 470 475 480 485 490 495
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AGT CTT GAC CCG GCA CCT CGG ATA CCC CAC CAT CTC TTC CAC GCC GTG
Ser Glu Leu Gly Arg Gly Ala Tyr Gly Val Val Glu Lys Val Arg His>
500 505 510 515 520 525 530 535 540 545
GCC CAG AGC GGC ACC ATC ATG GCC GTG AAG CGG ATC CGG GCC ACC GTG
CGG GTC TCG CCG TGG TAG TAC CGG CAC TTC GCC TAG GCC CGG TGG CAC
Ala Gln Ser Gly Thr Il Met Ala Val Lys Arg Ile Arg Ala Thr Val>
550 555 560 565 570 575 580 585 590 595
AAC TCA CAG GAG CAG AAG CGG CTG CTC ATG GAC CTG GAC ATC AAC ATG
TTG AGT GTC CTC GTC TTC GCC GAC GAG TAC CTG GAC CTG TAG TTG TAC
Asn Ser Gln Glu Gln Lys Arg Leu Leu Met Asp Leu Asp Ile Asn Met>

FIG. 4 - CONT'D

```
    600    605    610    615    620    625    630    635    640
     *      *      *      *      *      *      *
CGC ACG GTC GAC TGT TTC TAC ACT GTC ACC TTC TAC GGG GCA CTA TTC
GCG TGC CAG CTG ACA AAG ATG TGA CAG TGG AAG ATG CCC CGT GAT AAG
Arg Thr Val Asp Cys Phe Tyr Thr Val Thr Phe Tyr Gly Ala Leu Phe>

645    650    655    660    665    670    675    680    685    690
     *      *      *      *      *      *      *      *
AGA GAG GGA GAC GTG TGG ATC TGC ATG GAG CTC ATG GAC ACA TCC TTG
TCT CTC CCT CTG CAC ACC TAG ACG TAC CTC GAG TAC CTG TGT AGG AAC
Arg Glu Gly Asp Val Trp Ile Cys Met Glu Leu Met Asp Thr Ser Leu>

  695    700    705    710    715    720    725    730    735
     *      *      *      *      *      *
GAC AAG TTC TAC CGG AAG GTG CTG GAT AAA AAC ATG ACA ATT CCA GAG
CTG TTC AAG ATG GCC TTC CAC GAC CTA TTT TTG TAC TGT TAA GGT CTC
Asp Lys Phe Tyr Arg Lys Val Leu Asp Lys Asn Met Thr Ile Pro Glu>

740    745    750    755    760    765    770    775    780    785
 *      *      *      *      *      *      *      *
GAC ATC CTT GGG GAG ATT GCT GTG TCT ATC GTG CGG GCC CTG GAG CAT
CTG TAG GAA CCC CTC TAA CGA CAC AGA TAG CAC GCC CGG GAC CTC GTA
Asp Ile Leu Gly Glu Ile Ala Val Ser Ile Val Arg Ala Leu Glu His>

790    795    800    805    810    815    820    825    830    835
 *      *      *      *      *      *      *
CTG CAC AGC AAG CTG TCG GTG ATC CAC AGA GAT GTG AAG CCC TCC AAT
GAC GTG TCG TTC GAC AGC CAC TAG GTG TCT CTA CAC TTC GGG AGG TTA
Leu His Ser Lys Leu Ser Val Ile His Arg Asp Val Lys Pro Ser Asn>

    840    845    850    855    860    865    870    875    880
     *      *      *      *      *      *      *
GTC CTT ATC AAC AAG GAG GGC CAT GTG AAG ATG TGT GAC TTT GGC ATC
CAG GAA TAG TTG TTC CTC CCG GTA CAC TTC TAC ACA CTG AAA CCG TAG
Val Leu Ile Asn Lys Glu Gly His Val Lys Met Cys Asp Phe Gly Ile>

885    890    895    900    905    910    915    920    925    930
     *      *      *      *      *      *      *
AGT GGC TAC TTG GTG GAC TCT GTG GCC AAG ACG ATG GAT GCC GGC TGC
TCA CCG ATG AAC CAC CTG AGA CAC CGG TTC TGC TAC CTA CGG CCG ACG
Ser Gly Tyr Leu Val Asp Ser Val Ala Lys Thr Met Asp Ala Gly Cys>

  935    940    945    950    955    960    965    970    975
     *      *      *      *      *      *      *
AAG CCC TAC ATG GCC CCT GAG AGG ATC AAC CCA GAG CTG AAC CAG AAG
TTC GGG ATG TAC CGG GGA CTC TCC TAG TTG GGT CTC GAC TTG GTC TTC
Lys Pro Tyr Met Ala Pro Glu Arg Ile Asn Pro Glu Leu Asn Gln Lys>

980    985    990    995 1000   1005   1010 1015   1020   1025
 *      *      *      *      *      *      *      *
GGC TAC AAT GTC AAG TCC GAC GTC TGG AGC CTG GGC ATC ACC ATG ATT
CCG ATG TTA CAG TTC AGG CTG CAG ACC TCG GAC CCG TAG TGG TAC TAA
Gly Tyr Asn Val Lys Ser Asp Val Trp Ser Leu Gly Ile Thr Met Ile>

1030   1035   1040 1045   1050   1055 1060   1065   1070 1075
 *      *      *      *      *      *      *      *
GAG ATG GCC ATC CTG CGG TTC CCT TAC GAG TCC TGG GGG ACC CCG TTC
CTC TAC CGG TAG GAC GCC AAG GGA ATG CTC AGG ACC CCC TGG GGC AAG
Glu Met Ala Ile Leu Arg Phe Pro Tyr Glu Ser Trp Gly Thr Pro Phe>

  1080   1085 1090   1095   1100 1105   1110   1115 1120
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FIG. 4 - CONT'D

```
CAG CAG CTG AAG CAG GTG GTG GAG GAG CCG TCC CCC CAG CTC CCA GCC
GTC GTC GAC TTC GTC CAC CAC CTC CTC GGC AGG GGG GTC GAG GGT CGG
Gln Gln Leu Lys Gln Val Val Glu Glu Pro Ser Pro Gln Leu Pro Ala>

1125  1130  1135  1140  1145  1150  1155  1160  1165  1170

GAC CGT TTC TCC CCC GAG TTT GTG GAC TTC ACT GCT CAG TGC CTG AGG
CTG GCA AAG AGG GGG CTC AAA CAC CTG AAG TGA CGA GTC ACG GAC TCC
Asp Arg Phe Ser Pro Glu Phe Val Asp Phe Thr Ala Gln Cys Leu Arg>

1175  1180  1185  1190  1195  1200  1205  1210  1215

AAG AAC CCC GCA GAG CGT ATG AGC TAC CTG GAG CTG ATG GAG CAC CCC
TTC TTG GGG CGT CTC GCA TAC TCG ATG GAC CTC GAC TAC CTC GTG GGG
Lys Asn Pro Ala Glu Arg Met Ser Tyr Leu Glu Leu Met Glu His Pro>

1220  1225  1230  1235  1240  1245  1250  1255  1260  1265

TTC TTC ACC TTG CAC AAA ACC AAG AAG ACG GAC ATT GCT GCC TTC GTG
AAG AAG TGG AAC GTG TTT TGG TTC TTC TGC CTG TAA CGA CGG AAG CAC
Phe Phe Thr Leu His Lys Thr Lys Lys Thr Asp Ile Ala Ala Phe Val>

1270  1275  1280  1285  1290  1295 1300  1305 1310  1315 1320

AAG AAG ATC CTG GGA GAA GAC TCA TAGGGGCTG GGCCTCGGAC CCCACTCCGG
TTC TTC TAG GAC CCT CTT CTG AGT ATCCCCGAC CCGGAGCCTG GGGTGAGGCC
Lys Lys Ile Leu Gly Glu Asp Ser> (SEQ ID NO:2)

1325 1330  1335 1340  1345 1350  1355 1360  1365 1370  1375 1380

CCCTCCAGAG CCCCACAGCC CCATCTGCGG GGGCAGTGCT CACCCACACC ATAAGCTACT
GGGAGGTCTC GGGGTGTCGG GGTAGACGCC CCCGTCACGA GTGGGTGTGG TATTCGATGA

1385 1390  1395 1400  1405 1410  1415 1420  1425 1430  1435 1440

GCCATCCTGG CCCAGGGCAT CTGGGAGGAA CCGAGGGGGC TGCTCCCACC TGGCTCTGTG
CGGTAGGACC GGGTCCCGTA GACCCTCCTT GGCTCCCCCG ACGAGGGTGG ACCGAGACAC

1445 1450  1455 1460  1465 1470  1475 1480  1485 1490  1495 1500

GCGAGCCATT TGTCCCAAGT GCCAAAGAAG CAGACCATTG GGGCTCCCAG CCAGGCCCTT
CGCTCGGTAA ACAGGGTTCA CGGTTTCTTC GTCTGGTAAC CCCGAGGGTC GGTCCGGGAA

1505 1510  1515 1520  1525 1530  1535 1540  1545 1550  1555 1560

GTCGGCCCCA CCAGTGCCTC TCCCTGCTGC TCCTAGGACC CGTCTCCAGC TGCTGAGATC
CAGCCGGGGT GGTCACGGAG AGGGACGACG AGGATCCTGG GCAGAGGTCG ACGACTCTAG

1565 1570  1575 1580  1585 1590  1595 1600  1605 1610  1615 1620

CTGGACTGAG GGGGCCTGGA TGCCCCCTGT GGATGCTGCT GCCCCTGCAC AGCAGGCTGC
GACCTGACTC CCCCGGACCT ACGGGGGACA CCTACGACGA CGGGGACGTG TCGTCCGACG

1625 1630  1635 1640  1645 1650  1655 1660  1665 1670  1675 1680

CAGTGCCTGG GTGGATGGGC CACCGCCTTG CCCAGCCTGG ATGCCATCCA AGTTGTATAT
GTCACGGACC CACCTACCCG GTGGCGGAAC GGGTCGGACC TACGGTAGGT TCAACATATA

1685 1690  1695 1700  1705 1710  1715 1720  1725 1730  1735 1740

TTTTTTAATC TCTCGACTGA ATGGACTTTG CACACTTTGG CCCAGGGTGG CCACACCTCT
```

FIG..4 - CONT'D

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AAAAAATTAG AGAGCTGACT TACCTGAAAC GTGTGAAACC GGGTCCCACC GGTGTGGAGA

 1745 1750  1755 1760  1765 1770  1775 1780  1785 1790  1795 1800
          *         *         *         *         *         *
ATCCCGGCTT TGGTGCGGGG TACACAAGAG GGGATGAGTT GTGTGAATAC CCCAAGACTC
TAGGGCCGAA ACCACGCCCC ATGTGTTCTC CCCTACTCAA CACACTTATG GGGTTCTGAG

 1805 1810  1815 1820  1825 1830  1835 1840  1845 1850  1855 1860
          *         *         *         *         *         *
CCATGAGGGA GATGCCATGA GCCGCCCAAG GCCTTCCCCT GGCACTGGCA AACAGGGCCT
GGTACTCCCT CTACGGTACT CGGCGGGTTC CGGAAGGGGA CCGTGACCGT TTGTCCCGGA

 1865 1870  1875 1880  1885 1890  1895 1900  1905 1910  1915 1920
          *         *         *         *         *         *
CTGCGGAGCA CACTGGCTCA CCCAGTCCTG CCCGCCACCG TTATCGGTGT CATTCACCTT
GACGCCTCGT GTGACCGAGT GGGTCAGGAC GGGCGGTGGC AATAGCCACA GTAAGTGGAA

 1925 1930  1935 1940  1945 1950  1955 1960  1965 1970  1975 1980
          *         *         *         *         *         *
TCGTGTTTTT TTTAATTTAT CCTCTGTTGA TTTTTTCTTT TGCTTTATGG GTTTGGCTTG
AGCACAAAAA AAATTAAATA GGAGACAACT AAAAAAGAAA ACGAAATACC CAAACCGAAC

 1985 1990  1995 2000  2005 2010  2015 2020  2025 2030
          *         *         *         *         *
TTTTTCTTGC ATGGTTTGGA GCTGATCGCT TCTCCCCCAC CCCCTAGGGG (SEQ ID NO: 1)
AAAAAGAACG TACCAAACCT CGACTAGCGA AGAGGGGGTG GGGGATCCCC
```

FIG. 5

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     5   10    15   20    25   30    35   40    45   50    55   60
                *         *         *         *         *         *
TAGCTGCAGC ACAGCCTTCC CTAACGTTGC AACTGGGGGA AAAATCACTT TCCAGTCTGT
ATCGACGTCG TGTCGGAAGG GATTGCAACG TTGACCCCCT TTTTAGTGAA AGGTCAGACA

    65   70    75   80    85   90    95  100   105  110   115  120
                *         *         *         *         *         *
TTTGCAAGGT GTGCATTTCC ATCTTGATTC CCTGAAAGTC CATCTGCTGC ATCGGTCAAG
AAACGTTCCA CACGTAAAGG TAGAACTAAG GGACTTTCAG GTAGACGACG TAGCCAGTTC

   125  130   135  140   145  150   155  160   165  170   175  180
                *         *         *         *         *         *
AGAAACTCCA CTTGCATGAA GATTGCACGC CTGCAGCTTG CATCTTTGTT GCAAAACTAG
TCTTTGAGGT GAACGTACTT CTAACGTGCG GACGTCGAAC GTAGAAACAA CGTTTTGATC

   185  190   195  200   205  210   215  220   225  230   235  240
                *         *         *         *         *         *
CTACAGAAGA GAAGCAAGGC AAAGTCTTTT GTGCTCCCCT CCCCCATCAA AGGAAAGGGG
GATGTCTTCT CTTCGTTCCG TTTCAGAAAA CACGAGGGGA GGGGGTAGTT TCCTTTCCCC

    245    250   255    260   265   270    275    280   285
                 *         *         *         *
AAA ATG TCT CAG TCG AAA GGC AAG AAG CGA AAC CCT GGC CTT AAA ATT
TTT TAC AGA GTC AGC TTT CCG TTC TTC GCT TTG GGA CCG GAA TTT TAA
    Met Ser Gln Ser Lys Gly Lys Lys Arg Asn Pro Gly Leu Lys Ile>

290    295   300    305   310   315    320    325   330    335
 *         *         *         *         *         *         *
CCA AAA GAA GCA TTT GAA CAA CCT CAG ACC AGT TCC ACA CCA CCT AGA
GGT TTT CTT CGT AAA CTT GTT GGA GTC TGG TCA AGG TGT GGT GGA TCT
Pro Lys Glu Ala Phe Glu Gln Pro Gln Thr Ser Ser Thr Pro Pro Arg>

   340   345    350   355   360    365    370   375    380
                *         *         *         *         *
GAT TTA GAC TCC AAG GCT TGC ATT TCT ATT GGA AAT CAG AAC TTT GAG
CTA AAT CTG AGG TTC CGA ACG TAA AGA TAA CCT TTA GTC TTG AAA CTC
Asp Leu Asp Ser Lys Ala Cys Ile Ser Ile Gly Asn Gln Asn Phe Glu>

385   390    395   400   405    410    415   420    425    430
        *         *         *         *         *         *
GTG AAG GCA GAT GAC CTG GAG CCT ATA ATG GAA CTG GGA CGA GGT GCG
CAC TTC CGT CTA CTG GAC CTC GGA TAT TAC CTT GAC CCT GCT CCA CGC
Val Lys Ala Asp Asp Leu Glu Pro Ile Met Glu Leu Gly Arg Gly Ala>

  435    440   445   450    455   460   465    470   475   480
                *         *         *         *         *
TAC GGG GTG GTG GAG AAG ATG CGG CAC GTG CCC AGC GGG CAG ATC ATG
ATG CCC CAC CAC CTC TTC TAC GCC GTG CAC GGG TCG CCC GTC TAG TAC
Tyr Gly Val Val Glu Lys Met Arg His Val Pro Ser Gly Gln Ile Met>

    485    490   495    500   505   510    515    520   525
                 *         *         *         *
GCA GTG AAG CGG ATC CGA GCC ACA GTA AAT AGC CAG GAA CAG AAA CGG
CGT CAC TTC GCC TAG GCT CGG TGT CAT TTA TCG GTC CTT GTC TTT GCC
Ala Val Lys Arg Ile Arg Ala Thr Val Asn Ser Gln Glu Gln Lys Arg>

530    535   540    545   550   555    560    565   570    575
 *         *         *         *         *         *
CTA CTG ATG GAT TTG GAT ATT TCC ATG AGG ACG GTG GAC TGT CCA TTC
GAT GAC TAC CTA AAC CTA TAA AGG TAC TCC TGC CAC CTG ACA GGT AAG
```

FIG. 5 - CONT'D

```
Leu Leu Met Asp Leu Asp Ile Ser Met Arg Thr Val Asp Cys Pro Phe>

  580  585   590   595   600   605   610   615   620
   *     *     *     *     *     *     *

ACT GTC ACC TTT TAT GGC GCA CTG TTT CGG GAG GGT GAT GTG TGG ATC
TGA CAG TGG AAA ATA CCG CGT GAC AAA GCC CTC CCA CTA CAC ACC TAG
Thr Val Thr Phe Tyr Gly Ala Leu Phe Arg Glu Gly Asp Val Trp Ile>

625  630   635   640   645   650   655   660   665   670
   *     *     *     *     *     *     *     *

TGC ATG GAG CTC ATG GAT ACA TCA CTA GAT AAA TTC TAC AAA CAA GTT
ACG TAC CTC GAG TAC CTA TGT AGT GAT CTA TTT AAG ATG TTT GTT CAA
Cys Met Glu Leu Met Asp Thr Ser Leu Asp Lys Phe Tyr Lys Gln Val>

675  680   685   690   695   700   705   710   715   720
   *     *     *     *     *     *     *     *

ATT GAT AAA GGC CAG ACA ATT CCA GAG GAC ATC TTA GGG AAA ATA GCA
TAA CTA TTT CCG GTC TGT TAA GGT CTC CTG TAG AAT CCC TTT TAT CGT
Ile Asp Lys Gly Gln Thr Ile Pro Glu Asp Ile Leu Gly Lys Ile Ala>

  725  730   735   740   745   750   755   760   765
     *     *     *     *     *     *     *

GTT TCT ATT GTA AAA GCA TTA GAA CAT TTA CAT AGT AAG CTG TCT GTC
CAA AGA TAA CAT TTT CGT AAT CTT GTA AAT GTA TCA TTC GAC AGA CAG
Val Ser Ile Val Lys Ala Leu Glu His Leu His Ser Lys Leu Ser Val>

770  775   780   785   790   795   800   805   810   815
   *     *     *     *     *     *     *     *

ATT CAC AGA GAC GTC AAG CCT TCT AAT GTA CTC ATC AAT GCT CTC GGT
TAA GTG TCT CTG CAG TTC GGA AGA TTA CAT GAG TAG TTA CGA GAG CCA
Ile His Arg Asp Val Lys Pro Ser Asn Val Leu Ile Asn Ala Leu Gly>

  820  825   830   835   840   845   850   855   860
     *     *     *     *     *     *     *

CAA GTG AAG ATG TGC GAT TTT GGA ATC AGT GGC TAC TTG GTG GAC TCT
GTT CAC TTC TAC ACG CTA AAA CCT TAG TCA CCG ATG AAC CAC CTG AGA
Gln Val Lys Met Cys Asp Phe Gly Ile Ser Gly Tyr Leu Val Asp Ser>

865  870   875   880   885   890   895   900   905   910
   *     *     *     *     *     *     *     *

GTT GCT AAA ACA ATT GAT GCA GGT TGC AAA CCA TAC ATG GCC CCT GAA
CAA CGA TTT TGT TAA CTA CGT CCA ACG TTT GGT ATG TAC CGG GGA CTT
Val Ala Lys Thr Ile Asp Ala Gly Cys Lys Pro Tyr Met Ala Pro Glu>

915  920   925   930   935   940   945   950   955   960
   *     *     *     *     *     *     *     *

AGA ATA AAC CCA GAG CTC AAC CAG AAG GGA TAC AGT GTG AAG TCT GAC
TCT TAT TTG GGT CTC GAG TTG GTC TTC CCT ATG TCA CAC TTC AGA CTG
Arg Ile Asn Pro Glu Leu Asn Gln Lys Gly Tyr Ser Val Lys Ser Asp>

  965  970   975   980   985   990   995  1000  1005
     *     *     *     *     *     *     *

ATT TGG AGT CTG GGC ATC ACG ATG ATT GAG TTG GCC ATC CTT CGA TTT
TAA ACC TCA GAC CCG TAG TGC TAC TAA CTC AAC CGG TAG GAA GCT AAA
Ile Trp Ser Leu Gly Ile Thr Met Ile Glu Leu Ala Ile Leu Arg Phe>

1010  1015  1020  1025  1030  1035  1040  1045  1050  1055
   *     *     *     *     *     *     *

CCC TAT GAT TCA TGG GGA ACT CCA TTT CAG CAG CTC AAA CAG GTG GTA
GGG ATA CTA AGT ACC CCT TGA GGT AAA GTC GTC GAG TTT GTC CAC CAT
Pro Tyr Asp Ser Trp Gly Thr Pro Phe Gln Gln Leu Lys Gln Val Val>
```

FIG. 5 - CONT'D

```
  1060  1065   1070   1075  1080   1085   1090  1095   1100
     *           *           *           *           *
GAG GAG CCA TCG CCA CAA CTC CCA GCA GAC AAG TTC TCT GCA GAG TTT
CTC CTC GGT AGC GGT GTT GAG GGT CGT CTG TTC AAG AGA CGT CTC AAA
Glu Glu Pro Ser Pro Gln Leu Pro Ala Asp Lys Phe Ser Ala Glu Phe>

1105  1110   1115   1120  1125   1130   1135  1140   1145   1150
        *           *           *           *           *
GTT GAC TTT ACC TCA CAG TGC TTA AAG AAG AAT TCC AAA GAA CGG CCT
CAA CTG AAA TGG AGT GTC ACG AAT TTC TTC TTA AGG TTT CTT GCC GGA
Val Asp Phe Thr Ser Gln Cys Leu Lys Lys Asn Ser Lys Glu Arg Pro>

 1155   1160   1165  1170   1175   1180  1185   1190   1195  1200
          *           *           *           *           *
ACA TAC CCA GAG CTA ATG CAA CAT CCA TTT TTC ACC CTA CAT GAA TCC
TGT ATG GGT CTC GAT TAC GTT GTA GGT AAA AAG TGG GAT GTA CTT AGG
Thr Tyr Pro Glu Leu Met Gln His Pro Phe Phe Thr Leu His Glu Ser>

  1205   1210  1215   1220   1225  1230   1235   1240  1245  1250
           *           *           *           *           *
AAA GGA ACA GAT GTG GCA TCT TTT GTA AAA CTG ATT CTT GGA GAC TAAAA
TTT CCT TGT CTA CAC CGT AGA AAA CAT TTT GAC TAA GAA CCT CTG ATTTT
Lys Gly Thr Asp Val Ala Ser Phe Val Lys Leu Ile Leu Gly Asp> (SEQ ID NO:4)

 1255 1260  1265 1270  1275 1280  1285 1290  1295 1300  1305 1310
        *           *           *           *           *
AGCAGTGGAC TTAATCGGTT GACCCTACTG TGGATTGGTG GGTTTCGGGG TGAAGCAAGT
TCGTCACCTG AATTAGCCAA CTGGGATGAC ACCTAACCAC CCAAAGCCCC ACTTCGTTCA

 1315 1320  1325 1330  1335 1340  1345 1350  1355 1360  1365 1370
        *           *           *           *           *
TCACTACAGC ATCAATAGAA AGTCATCTTT GAGATAATTT AACCCTGCCT CTCAGAGGGT
AGTGATGTCG TAGTTATCTT TCAGTAGAAA CTCTATTAAA TTGGGACGGA GAGTCTCCCA

 1375 1380  1385 1390  1395 1400  1405 1410  1415 1420  1425 1430
        *           *           *           *           *
TTTCTCTCCC AATTTTCTTT TTACTCCCCC TCTTAAGGGG GCCTTGGAAT CTATAGTATA
AAAGAGAGGG TTAAAAGAAA AATGAGGGGG AGAATTCCCC CGGAACCTTA GATATCATAT

 1435 1440  1445 1450  1455 1460  1465 1470  1475 1480  1485 1490
        *           *           *           *           *
GAATGAACTG TCTAGATGGA TGAATTATGA TAAAGGCTTA GGACTTCAAA AGGTGATTAA
CTTACTTGAC AGATCTACCT ACTTAATACT ATTTCCGAAT CCTGAAGTTT TCCACTAATT

 1495 1500  1505 1510  1515 1520  1525 1530  1535 1540  1545 1550
        *           *           *           *           *
ATATTTAATG ATGTGTCATA TGAGTCCTCA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA
TATAAATTAC TACACAGTAT ACTCAGGAGT TTTTTTTTTT TTTTTTTTTT TTTTTTTTTT

 1555 1560  1565 1570  1575 1580  1585 1590  1595 1600
        *           *           *           *           *
AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AAAAAAAAAA AA  (SEQ ID NO:3)
TTTTTTTTTT TTTTTTTTTT TTTTTTTTTT TTTTTTTTTT TTTTTTTTTT TT
```

FIG. 6

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     5   10    15   20    25   30    35   40    45   50    55
                 *         *         *         *         *
CTAGGGTCCC CGGCGCCAGG CCACCCGGCC GTCAGCAGC ATG CAG GGT AAA CGC AAA
GATCCCAGGG GCCGCGGTCC GGTGGGCCGG CAGTCGTCG TAC GTC CCA TTT GCG TTT
                                           Met Gln Gly Lys Arg Lys>

  60    65    70    75    80    85    90    95   100   105
   *         *         *         *         *         *
GCA CTG AAG TTG AAT TTT GCA AAT CCA CCT TTC AAA TCT ACA GCA AGG
CGT GAC TTC AAC TTA AAA CGT TTA GGT GGA AAG TTT AGA TGT CGT TCC
Ala Leu Lys Leu Asn Phe Ala Asn Pro Pro Phe Lys Ser Thr Ala Arg>

    110   115   120   125   130   135   140   145   150
      *         *         *         *         *         *
TTT ACT CTG AAT CCC AAT CCT ACA GGA GTT CAA AAC CCA CAC ATA GAG
AAA TGA GAC TTA GGG TTA GGA TGT CCT CAA GTT TTG GGT GTG TAT CTC
Phe Thr Leu Asn Pro Asn Pro Thr Gly Val Gln Asn Pro His Ile Glu>

155   160   165   170   175   180   185   190   195   200
        *         *         *         *         *         *
AGA CTG AGA ACA CAC AGC ATT GAG TCA TCA GGA AAA CTG AAG ATC TCC
TCT GAC TCT TGT GTG TCG TAA CTC AGT AGT CCT TTT GAC TTC TAG AGG
Arg Leu Arg Thr His Ser Ile Glu Ser Ser Gly Lys Leu Lys Ile Ser>

  205   210   215   220   225   230   235   240   245
          *         *         *         *         *
CCT GAA CAA CAC TGG GAT TTC ACT GCA GAG GAC TTG AAA GAC CTT GGA
GGA CTT GTT GTG ACC CTA AAG TGA CGT CTC CTG AAC TTT CTG GAA CCT
Pro Glu Gln His Trp Asp Phe Thr Ala Glu Asp Leu Lys Asp Leu Gly>

250   255   260   265   270   275   280   285   290   295
  *         *         *         *         *         *
GAA ATT GGA CGA GGA GCT TAT GGT TCT GTC AAC AAA ATG GTC CAC AAA
CTT TAA CCT GCT CCT CGA ATA CCA AGA CAG TTG TTT TAC CAG GTG TTT
Glu Ile Gly Arg Gly Ala Tyr Gly Ser Val Asn Lys Met Val His Lys>

 300   305   310   315   320   325   330   335   340   345
   *         *         *         *         *         *
CCA AGT GGG CAA ATA ATG GCA GTT AAA AGA ATT CGG TCA ACA GTG GAT
GGT TCA CCC GTT TAT TAC CGT CAA TTT TCT TAA GCC AGT TGT CAC CTA
Pro Ser Gly Gln Ile Met Ala Val Lys Arg Ile Arg Ser Thr Val Asp>

    350   355   360   365   370   375   380   385   390
      *         *         *         *         *         *
GAA AAA GAA CAA AAA CAA CTT CTT ATG GAT TTG GAT GTA GTA ATG CGG
CTT TTT CTT GTT TTT GTT GAA GAA TAC CTA AAC CTA CAT CAT TAC GCC
Glu Lys Glu Gln Lys Gln Leu Leu Met Asp Leu Asp Val Val Met Arg>

395   400   405   410   415   420   425   430   435   440
        *         *         *         *         *         *
AGT AGT GAT TGC CCA TAC ATT GTT CAG TTT TAT GGT GCA CTC TTC AGA
TCA TCA CTA ACG GGT ATG TAA CAA GTC AAA ATA CCA CGT GAG AAG TCT
Ser Ser Asp Cys Pro Tyr Ile Val Gln Phe Tyr Gly Ala Leu Phe Arg>

  445   450   455   460   465   470   475   480   485
          *         *         *         *         *
GAG GGT GAC TGT TGG ATC TGT ATG GAA CTC ATG TCT ACC TCG TTT GAT
CTC CCA CTG ACA ACC TAG ACA TAC CTT GAG TAC AGA TGG AGC AAA CTA
Glu Gly Asp Cys Trp Ile Cys Met Glu Leu Met Ser Thr Ser Phe Asp>
```

FIG. 6 - CONT'D

```
490   495   500   505   510   515   520   525   530   535
 *     *     *     *     *     *     *     *     *     *
AAG TTT TAC AAA TAT GTA TAT AGT GTA TTA GAT GAT GTT ATT CCA GAA
TTC AAA ATG TTT ATA CAT ATA TCA CAT AAT CTA CTA CAA TAA GGT CTT
Lys Phe Tyr Lys Tyr Val Tyr Ser Val Leu Asp Asp Val Ile Pro Glu>

540   545   550   555   560   565   570   575   580   585
 *     *     *     *     *     *     *     *     *     *
GAA ATT TTA GGC AAA ATC ACT TTA GCA ACT GTG AAA GCA CTA AAC CAC
CTT TAA AAT CCG TTT TAG TGA AAT CGT TGA CAC TTT CGT GAT TTG GTG
Glu Ile Leu Gly Lys Ile Thr Leu Ala Thr Val Lys Ala Leu Asn His>

590   595   600   605   610   615   620   625   630
 *     *     *     *     *     *     *     *     *
TTA AAA GAA AAC TTG AAA ATT ATT CAC AGA GAT ATC AAA CCT TCC AAT
AAT TTT CTT TTG AAC TTT TAA TAA GTG TCT CTA TAG TTT GGA AGG TTA
Leu Lys Glu Asn Leu Lys Ile Ile His Arg Asp Ile Lys Pro Ser Asn>

635   640   645   650   655   660   665   670   675   680
 *     *     *     *     *     *     *     *     *     *
ATT CTT CTG GAC AGA AGT GGA AAT ATT AAG CTC TGT GAC TTC GGC ATC
TAA GAA GAC CTG TCT TCA CCT TTA TAA TTC GAG ACA CTG AAG CCG TAG
Ile Leu Leu Asp Arg Ser Gly Asn Ile Lys Leu Cys Asp Phe Gly Ile>

685   690   695   700   705   710   715   720   725
 *     *     *     *     *     *     *     *     *
AGT GGA CAG CTT GTG GAC TCT ATT GCC AAG ACA AGA GAT GCT GGC TGT
TCA CCT GTC GAA CAC CTG AGA TAA CGG TTC TGT TCT CTA CGA CCG ACA
Ser Gly Gln Leu Val Asp Ser Ile Ala Lys Thr Arg Asp Ala Gly Cys>

730   735   740   745   750   755   760   765   770   775
 *     *     *     *     *     *     *     *     *     *
AGG CCA TAC ATG GCA CCT GAA AGA ATA GAC CCA AGC GCA TCA CGA CAA
TCC GGT ATG TAC CGT GGA CTT TCT TAT CTG GGT TCG CGT AGT GCT GTT
Arg Pro Tyr Met Ala Pro Glu Arg Ile Asp Pro Ser Ala Ser Arg Gln>

780   785   790   795   800   805   810   815   820   825
 *     *     *     *     *     *     *     *     *     *
GGA TAT GAT GTC CGC TCT GAT GTC TGG AGT TTG GGG ATC ACA TTG TAT
CCT ATA CTA CAG GCG AGA CTA CAG ACC TCA AAC CCC TAG TGT AAC ATA
Gly Tyr Asp Val Arg Ser Asp Val Trp Ser Leu Gly Ile Thr Leu Tyr>

830   835   840   845   850   855   860   865   870
 *     *     *     *     *     *     *     *     *
GAG TTG GCC ACA GGC CGA TTT CCT TAT CCA AAG TGG AAT AGT GTA TTT
CTC AAC CGG TGT CCG GCT AAA GGA ATA GGT TTC ACC TTA TCA CAT AAA
Glu Leu Ala Thr Gly Arg Phe Pro Tyr Pro Lys Trp Asn Ser Val Phe>

875   880   885   890   895   900   905   910   915   920
 *     *     *     *     *     *     *     *     *     *
GAT CAA CTA ACA CAA GTC GTG AAA GGA GAT CCT CCG CAG CTG AGT AAT
CTA GTT GAT TGT GTT CAG CAC TTT CCT CTA GGA GGC GTC GAC TCA TTA
Asp Gln Leu Thr Gln Val Val Lys Gly Asp Pro Pro Gln Leu Ser Asn>

925   930   935   940   945   950   955   960   965
 *     *     *     *     *     *     *     *     *
TCT GAG GAA AGG GAA TTC TCC CCG AGT TTC ATC AAC TTT GTC AAC TTG
AGA CTC CTT TCC CTT AAG AGG GGC TCA AAG TAG TTG AAA CAG TTG AAC
Ser Glu Glu Arg Glu Phe Ser Pro Ser Phe Ile Asn Phe Val Asn Leu>

970   975   980   985   990   995  1000  1005  1010  1015
 *     *     *     *     *     *     *     *     *     *
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FIG. 6 - CONT'D

```
TGC CTT ACG AAG GAT GAA TCC AAA AGG CCA AAG TAT AAA GAG CTT CTG
ACG GAA TGC TTC CTA CTT AGG TTT TCC GGT TTC ATA TTT CTC GAA GAC
Cys Leu Thr Lys Asp Glu Ser Lys Arg Pro Lys Tyr Lys Glu Leu Leu>

1020   1025   1030  1035   1040   1045  1050   1055   1060  1065
  *      *      *      *      *      *      *      *      *

AAA CAT CCC TTT ATT TTG ATG TAT GAA GAA CGT GCC GTT GAG GTC GCA
TTT GTA GGG AAA TAA AAC TAC ATA CTT CTT GCA CGG CAA CTC CAG CGT
Lys His Pro Phe Ile Leu Met Tyr Glu Glu Arg Ala Val Glu Val Ala>

  1070   1075  1080   1085   1090  1095   1100   1105  1110
    *      *      *      *      *      *      *      *

TGC TAT GTT TGT AAA ATC CTG GAT CAA ATG CCA GCT ACT CCC AGC TCT
ACG ATA CAA ACA TTT TAG GAC CTA GTT TAC GGT CGA TGA GGG TCG AGA
Cys Tyr Val Cys Lys Ile Leu Asp Gln Met Pro Ala Thr Pro Ser Ser>

1115   1120  1125   1130  1135 1140  1145 1150  1155 1160  1165 1170
         *      *      *      *      *      *      *      *

CCC ATG TAT GTC GAT TG ATATCGYTGC TACATCAGAC TCTAGAAAAA AGGGCTGAGA
GGG TAC ATA CAG CTA AC TATAGCRACG ATGTAGTCTG AGATCTTTTT TCCCGACTCT
Pro Met Tyr Val Asp>
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(SEQ ID NO:6)

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 1175 1180  1185 1190  1195 1200  1205 1210  1215 1220  1225 1230
         *      *      *      *      *      *      *      *

GGAAGCAAGA CGTAAAGAAT TTTCATCCCG TATCACAGTG TTTTTATTGC TCGCCCAGAC
CCTTCGTTCT GCATTTCTTA AAAGTAGGGC ATAGTGTCAC AAAAATAACG AGCGGGTCTG

 1235 1240  1245 1250  1255 1260  1265 1270  1275 1280  1285 1290
         *      *      *      *      *      *      *      *

ACCATGTGCA ATAAGATTGG TGTTCGTTTC CATCATGTCT GTATACTCCT GTCACCTAGA
TGGTACACGT TATTCTAACC ACAAGCAAAG GTAGTACAGA CATATGAGGA CAGTGGATCT

 1295 1300  1305 1310  1315 1320  1325 1330  1335 1340  1345 1350
         *      *      *      *      *      *      *      *

ACGTGCATCC TTGTAATACC TGATTGATCA CACAGTGTTA GTGCTGGTCA GAGAGACCTC
TGCACGTAGG AACATTATGG ACTAACTAGT GTGTCACAAT CACGACCAGT CTCTCTGGAG

 1355 1360  1365 1370  1375 1380  1385 1390  1395 1400  1405 1410
         *      *      *      *      *      *      *      *

ATCCTGCTCT TTTGTGATGA ACATATTCAT GAAATGTGGA AGTCAGTACG ATCAAGTTGT
TAGGACGAGA AAACACTACT TGTATAAGTA CTTTACACCT TCAGTCATGC TAGTTCAACA

 1415 1420  1425 1430  1435 1440  1445 1450  1455 1460  1465 1470
         *      *      *      *      *      *      *      *

TGACTGTGAT TAGATCACAT CTTAAATTCA TTTCTAGACT CAAAACCTGG AGATGCAGCT
ACTGACACTA ATCTAGTGTA GAATTTAAGT AAAGATCTGA GTTTTGGACC TCTACGTCGA

 1475 1480  1485 1490  1495 1500  1505 1510  1515 1520  1525 1530
         *      *      *      *      *      *      *      *

ACTGGAATGG TGTTTTGTCA GACTTCCAAA TCCTGGAAGG ACACAGTGAT GAATGTACTA
TGACCTTACC ACAAAACAGT CTGAAGGTTT AGGACCTTCC TGTGTCACTA CTTACATGAT

 1535 1540  1545 1550  1555 1560  1565 1570  1575 1580  1585 1590
         *      *      *      *      *      *      *      *

TATCTGAACA TAGAAACTCG GGCTTGAGTG AGAAGAGCTT GCACAGCCAA CGAGACACAT
ATAGACTTGT ATCTTTGAGC CCGAACTCAC TCTTCTCGAA CGTGTCGGTT GCTCTGTGTA

 1595 1600  1605 1610  1615 1620  1625 1630  1635 1640  1645 1650
         *      *      *      *      *      *      *      *

TGCCTTCTGG AGCTGGGAGA CAAAGGAGGA ATTTACTTTC TTCACCAAGT GCAATAGATT
ACGGAAGACC TCGACCCTCT GTTTCCTCCT TAAATGAAAG AAGTGGTTCA CGTTATCTAA
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FIG. 6 - CONT'D

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1655 1660  1665 1670  1675 1680  1685 1690  1695 1700  1705 1710
ACTGATGTGA TATTCTGTTG CTTTACAGTT ACAGTTGATG TTTGGGGATC GATGTGCTCA
TGACTACACT ATAAGACAAC GAAATGTCAA TGTCAACTAC AAACCCCTAG CTACACGAGT

1715 1720  1725 1730  1735 1740  1745 1750  1755 1760  1765 1770
GCCAAATTTC CTGTTTGAAA TATCATGTTA AATTAGAATG AATTTATCTT TACCAAAAAC
CGGTTTAAAG GACAAACTTT ATAGTACAAT TTAATCTTAC TTAAATAGAA ATGGTTTTTG

1775 1780  1785 1790  1795 1800  1805 1810  1815 1820  1825 1830
CATGTTGCGT TCAAAGAGGT GAACATTAAA ATATAGAGAC AGGACAGAAT GTGTTCTTTT
GTACAACGCA AGTTTCTCCA CTTGTAATTT TATATCTCTG TCCTGTCTTA CACAAGAAAA

1835 1840  1845 1850  1855 1860  1865 1870  1875 1880  1885 1890
CTCCTCTACC AGTCCTATTT TTCAATGGGA AGACTCAGGA GTCTGCCACT TGTCAAAGAA
GAGGAGATGG TCAGGATAAA AAGTTACCCT TCTGAGTCCT CAGACGGTGA ACAGTTTCTT

1895 1900  1905 1910  1915 1920  1925 1930  1935 1940  1945 1950
GGTGCTGATC CTAAGAATTT TTCATTCTCA GAATTCGGTG TGCTGCCAAC TTGATGTTCC
CCACGACTAG GATTCTTAAA AAGTAAGAGT CTTAAGCCAC ACGACGGTTG AACTACAAGG

1955 1960  1965 1970  1975 1980  1985 1990  1995 2000  2005 2010
ACCTGCCACA AACCACCAGG ACTGAAAGAA GAAAACAGTA CAGAAGGCAA AGTTTACAGA
TGGACGGTGT TTGGTGGTCC TGACTTTCTT CTTTTGTCAT GTCTTCCGTT TCAAATGTCT

2015 2020  2025 2030  2035 2040  2045 2050  2055 2060  2065 2070
TGTTTTTAAT TCTAGTATTT TATCTGGAAC AACTTGTAGC AGCTATATAT TTCCCCTTGG
ACAAAAATTA AGATCATAAA ATAGACCTTG TTGAACATCG TCGATATATA AAGGGGAACC

2075 2080  2085 2090  2095 2100  2105 2110  2115 2120  2125 2130
TCCCAAGCCT GATACTTTAG CCATCATAAC TCACTAACAG GGAGAAGTAG CTAGTAGCAA
AGGGTTCGGA CTATGAAATC GGTAGTATTG AGTGATTGTC CCTCTTCATC GATCATCGTT

2135 2140  2145 2150  2155 2160  2165 2170  2175 2180  2185 2190
TGTGCCTTGA TTGATTAGAT AAAGATTTCT AGTAGGCAGC AAAAGACCAA ATCTCAGTTG
ACACGGAACT AACTAATCTA TTTCTAAAGA TCATCCGTCG TTTTCTGGTT TAGAGTCAAC

2195 2200  2205 2210  2215 2220  2225 2230  2235 2240  2245 2250
TTTGCTTCTT GCCATCACTG GTCCAGGTCT TCAGTTTCCG AATCTCTTTC CCTTCCCCTG
AAACGAAGAA CGGTAGTGAC CAGGTCCAGA AGTCAAAGGC TTAGAGAAAG GGAAGGGGAC

2255 2260  2265 2270  2275 2280  2285 2290  2295 2300  2305 2310
TGGTCTATTG TCGCTATGTG ACTTGCGCTT AATCCAATAT TTTGCCTTTT TTCTATATCA
ACCAGATAAC AGCGATACAC TGAACGCGAA TTAGGTTATA AAACGGAAAA AAGATATAGT

2315 2320  2325 2330  2335 2340  2345 2350  2355 2360  2365 2370
AAAAACCTTT ACAGTTAGCA GGGATGTTCC TTACCGAGGA TTTTTAACCC CCAATCTCTC
TTTTTGGAAA TGTCAATCGT CCCTACAAGG AATGGCTCCT AAAAATTGGG GGTTAGAGAG

2375 2380  2385 2390  2395 2400  2405 2410  2415 2420  2425 2430
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FIG. 6 - CONT'D

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ATAATCGCTA GTGTTTAAAA GGCTAAGAAT AGTGGGGCCC AACCGATGTG GTAGGTGATA
TATTAGCGAT CACAAATTTT CCGATTCTTA TCACCCCGGG TTGGCTACAC CATCCACTAT

 2435 2440  2445 2450  2455 2460  2465 2470  2475 2480  2485 2490
          *         *         *         *         *         *
AAGAGGCATC TTTTCTAGAG ACACATTGGA CCAGATGAGG ATCCGAAACG GCAGCCTTTA
TTCTCCGTAG AAAAGATCTC TGTGTAACCT GGTCTACTCC TAGGCTTTGC CGTCGGAAAT

 2495 2500  2505 2510  2515 2520  2525 2530  2535 2540  2545 2550
          *         *         *         *         *         *
CGTTCATCAC CTGCTAGAAC CTCTCGTAGT CCATCACCAT TTCTTGGCAT TGGAATTCTA
GCAAGTAGTG GACGATCTTG GAGAGCATCA GGTAGTGGTA AAGAACCGTA ACCTTAAGAT

 2555 2560  2565 2570  2575 2580  2585 2590  2595 2600  2605 2610
          *         *         *         *         *         *
CTGGAAAAAA ATACAAAAAG CAAAACAAAA CCCTCAGCAC TGTTACAAGA GGCCATTTAA
GACCTTTTTT TATGTTTTTC GTTTTGTTTT GGGAGTCGTG ACAATGTTCT CCGGTAAATT

 2615 2620  2625 2630  2635 2640  2645 2650  2655 2660  2665 2670
          *         *         *         *         *         *
GTATCTTGTG CTTCTTCACT TACCCATTAG CCAGGTTCTC ATTAGGTTTT GCTTGGGCCT
CATAGAACAC GAAGAAGTGA ATGGGTAATC GGTCCAAGAG TAATCCAAAA CGAACCCGGA

 2675 2680  2685 2690  2695 2700  2705 2710  2715 2720  2725 2730
          *         *         *         *         *         *
CCCTGGCACT GAACCTTAGG CTTTGTATGA CAGTGAAGCA GCACTGTGAG TGGTTCAAGC
GGGACCGTGA CTTGGAATCC GAAACATACT GTCACTTCGT CGTGACACTC ACCAAGTTCG

 2735 2740  2745 2750  2755 2760  2765 2770  2775 2780  2785 2790
          *         *         *         *         *         *
ACACTGGAAT ATAAAACAGT CATGGCCTGA GATGCAGGTG ATGCCATTAC AGAACCAAAT
TGTGACCTTA TATTTTGTCA GTACCGGACT CTACGTCCAC TACGGTAATG TCTTGGTTTA

 2795 2800  2805 2810  2815 2820  2825 2830  2835 2840  2845 2850
          *         *         *         *         *         *
CGTGGCACGT ATTGCTGTGT CTCCTCTCAG AGTGACAGTC ATAAATACTG TCAAACAATA
GCACCGTGCA TAACGACACA GAGGAGAGTC TCACTGTCAG TATTTATGAC AGTTTGTTAT

 2855 2860  2865 2870  2875 2880  2885 2890  2895 2900  2905 2910
          *         *         *         *         *         *
AAGGGAGAAT GGTGCTGTTT AAAGTCACAT CCCTGTAAAT TGCAGAATTC AAAAGTGATT
TTCCCTCTTA CCACGACAAA TTTCAGTGTA GGGACATTTA ACGTCTTAAG TTTTCACTAA

 2915 2920  2925 2930  2935 2940  2945 2950  2955 2960  2965 2970
          *         *         *         *         *         *
ATCTCTTTGA TCTACTTGCC TCATTTCCCT ATCTTCTCCC CCACGGTATC CTAAACTTTA
TAGAGAAACT AGATGAACGG AGTAAAGGGA TAGAAGAGGG GGTGCCATAG GATTTGAAAT

 2975 2980  2985 2990  2995 3000  3005 3010  3015 3020  3025 3030
          *         *         *         *         *         *
GACTTCCCAC TGTTCTGAAA GGAGACATTG CTCTATGTCT GCCTTCGACC ACAGCAAGCC
CTGAAGGGTG ACAAGACTTT CCTCTGTAAC GAGATACAGA CGGAAGCTGG TGTCGTTCGG

 3035 3040  3045 3050  3055 3060  3065 3070  3075 3080  3085 3090
          *         *         *         *         *         *
ATCATCCTCC ATTGCTCCCG GGGACTCAAG AGGAATCTGT TTCTCTGCTG TCAACTTCCC
TAGTAGGAGG TAACGAGGGC CCCTGAGTTC TCCTTAGACA AAGAGACGAC AGTTGAAGGG

 3095 3100  3105 3110  3115 3120  3125 3130  3135 3140  3145 3150
          *         *         *         *         *         *
ATCTGGCTCA GCATAGGGTC ACTTTGCCAT TATGCAAATG GAGATAAAAG CAATTCTGGC
TAGACCGAGT CGTATCCCAG TGAAACGGTA ATACGTTTAC CTCTATTTTC GTTAAGACCG
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FIG. 6 - CONT'D

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 3155 3160  3165 3170  3175 3180  3185 3190  3195 3200  3205 3210
          *         *         *         *         *         *
TGTCCAGGAG CTAATCTGAC CGTTCTATTG TGTGGATGAC CACATAAGAA GGCAATTTTA
ACAGGTCCTC GATTAGACTG GCAAGATAAC ACACCTACTG GTGTATTCTT CCGTTAAAAT

 3215 3220  3225 3230  3235 3240  3245 3250  3255 3260  3265 3270
          *         *         *         *         *         *
GTGTATTAAT CATAGATTAT TATAAACTAT AAACTTAAGG GCAAGGAGTT TATTACAATG
CACATAATTA GTATCTAATA ATATTTGATA TTTGAATTCC CGTTCCTCAA ATAATGTTAC

 3275 3280  3285 3290  3295 3300  3305 3310  3315 3320  3325 3330
          *         *         *         *         *         *
TATCTTTATT AAAACAAAAG GGTGTATAGT GTTCACAAAC TGTGAAAATA GTGTAAGAAC
ATAGAAATAA TTTTGTTTTC CCACATATCA CAAGTGTTTG ACACTTTTAT CACATTCTTG

 3335 3340  3345 3350  3355 3360  3365 3370  3375 3380  3385 3390
          *         *         *         *         *         *
TGTACATTGT GAGCTCTGGT TATTTTTCTC TTGTACCATA GAAAAATGTA TAAAAATTAT
ACATGTAACA CTCGAGACCA ATAAAAAGAG AACATGGTAT CTTTTTACAT ATTTTTAATA

 3395 3400  3405 3410  3415 3420  3425 3430  3435 3440  3445 3450
          *         *         *         *         *         *
CAAAAAGCTA ATGTGCAGGG ATATTGCCTT ATTTGTCTGT AAAAAATGGA GCTCAGTAAC
GTTTTTCGAT TACACGTCCC TATAACGGAA TAAACAGACA TTTTTTACCT CGAGTCATTG

 3455 3460  3465 3470  3475 3480  3485 3490  3495
          *         *         *         *
ATAACTGCTT CTTGGAGCTT TGGAATATTT TATCCTGTAT TCTTGTTT  (SEQ ID NO:5)
TATTGACGAA GAACCTCGAA ACCTTATAAA ATAGGACATA AGAACAAA
```

FIG. 7

```
     5     10     15     20     25     30     35     40     45     50
           *      *      *      *      *      *      *      *
CAACA ATG GCG GCT CCG AGC CCG AGC GGT GGC GGC GGC AGC GGC ACC CCC
GTTGT TAC CGC CGA GGC TCG GGC TCG CCA CCG CCG CCG TCG CCG TGG GGG
      Met Ala Ala Pro Ser Pro Ser Gly Gly Gly Gly Ser Gly Thr Pro>

     55     60     65     70     75     80     85     90     95
            *      *      *      *      *      *
GGC CCC GTA GGG TCC CCG GCG CCA GGC CAC CCG GCC GTC AGC AGC ATG
CCG GGG CAT CCC AGG GGC CGC GGT CCG GTG GGC CGG CAG TCG TCG TAC
Gly Pro Val Gly Ser Pro Ala Pro Gly His Pro Ala Val Ser Ser Met>

 100    105    110    115    120    125    130    135    140    145
  *             *      *      *      *             *      *
CAG GGT AAA CGC AAA GCA CTG AAG TTG AAT TTT GCA AAT CCA CCT TTC
GTC CCA TTT GCG TTT CGT GAC TTC AAC TTA AAA CGT TTA GGT GGA AAG
Gln Gly Lys Arg Lys Ala Leu Lys Leu Asn Phe Ala Asn Pro Pro Phe>

   150    155    160    165    170    175    180    185    190
     *             *      *             *             *
AAA TCT ACA GCA AGG TTT ACT CTG AAT CCC AAT CCT ACA GGA GTT CAA
TTT AGA TGT CGT TCC AAA TGA GAC TTA GGG TTA GGA TGT CCT CAA GTT
Lys Ser Thr Ala Arg Phe Thr Leu Asn Pro Asn Pro Thr Gly Val Gln>

195   200    205    210    215    220    225    230    235    240
        *      *             *      *             *      *
AAC CCA CAC ATA GAG AGA CTG AGA ACA CAC AGC ATT GAG TCA TCA GGA
TTG GGT GTG TAT CTC TCT GAC TCT TGT GTG TCG TAA CTC AGT AGT CCT
Asn Pro His Ile Glu Arg Leu Arg Thr His Ser Ile Glu Ser Ser Gly>

 245    250    255    260    265    270    275    280    285    290
          *      *             *      *             *      *
AAA CTG AAG ATC TCC CCT GAA CAA CAC TGG GAT TTC ACT GCA GAG GAC
TTT GAC TTC TAG AGG GGA CTT GTT GTG ACC CTA AAG TGA CGT CTC CTG
Lys Leu Lys Ile Ser Pro Glu Gln His Trp Asp Phe Thr Ala Glu Asp>

    295    300    305    310    315    320    325    330    335
           *      *      *      *             *
TTG AAA GAC CTT GGA GAA ATT GGA CGA GGA GCT TAT GGT TCT GTC AAC
AAC TTT CTG GAA CCT CTT TAA CCT GCT CCT CGA ATA CCA AGA CAG TTG
Leu Lys Asp Leu Gly Glu Ile Gly Arg Gly Ala Tyr Gly Ser Val Asn>

 340    345    350    355    360    365    370    375    380    385
  *             *      *      *      *             *
AAA ATG GTC CAC AAA CCA AGT GGG CAA ATA ATG GCA GTT AAA AGA ATT
TTT TAC CAG GTG TTT GGT TCA CCC GTT TAT TAC CGT CAA TTT TCT TAA
Lys Met Val His Lys Pro Ser Gly Gln Ile Met Ala Val Lys Arg Ile>

   390    395    400    405    410    415    420    425    430
     *             *      *             *             *
CGG TCA ACA GTG GAT GAA AAA GAA CAA AAA CAA CTT CTT ATG GAT TTG
GCC AGT TGT CAC CTA CTT TTT CTT GTT TTT GTT GAA GAA TAC CTA AAC
Arg Ser Thr Val Asp Glu Lys Glu Gln Lys Gln Leu Leu Met Asp Leu>

435   440    445    450    455    460    465    470    475    480
        *      *             *      *             *      *
GAT GTA GTA ATG CGG AGT AGT GAT TGC CCA TAC ATT GTT CAG TTT TAT
CTA CAT CAT TAC GCC TCA TCA CTA ACG GGT ATG TAA CAA GTC AAA ATA
Asp Val Val Met Arg Ser Ser Asp Cys Pro Tyr Il  Val Gln Phe Tyr>
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FIG. 7 - CONT'D

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485    490    495    500    505    510    515    520    525    530
GGT GCA CTC TTC AGA GAG GGT GAC TGT TGG ATC TGT ATG GAA CTC ATG
CCA CGT GAG AAG TCT CTC CCA CTG ACA ACC TAG ACA TAC CTT GAG TAC
Gly Ala Leu Phe Arg Glu Gly Asp Cys Trp Ile Cys Met Glu Leu Met>

   535    540    545    550    555    560    565    570    575
TCT ACC TCG TTT GAT AAG TTT TAC AAA TAT GTA TAT AGT GTA TTA GAT
AGA TGG AGC AAA CTA TTC AAA ATG TTT ATA CAT ATA TCA CAT AAT CTA
Ser Thr Ser Phe Asp Lys Phe Tyr Lys Tyr Val Tyr Ser Val Leu Asp>

580    585    590    595    600    605    610    615    620    625
GAT GTT ATT CCA GAA GAA ATT TTA GGC AAA ATC ACT TTA GCA ACT GTG
CTA CAA TAA GGT CTT CTT TAA AAT CCG TTT TAG TGA AAT CGT TGA CAC
Asp Val Ile Pro Glu Glu Ile Leu Gly Lys Ile Thr Leu Ala Thr Val>

   630    635    640    645    650    655    660    665    670
AAA GCA CTA AAC CAC TTA AAA GAA AAC TTG AAA ATT ATT CAC AGA GAT
TTT CGT GAT TTG GTG AAT TTT CTT TTG AAC TTT TAA TAA GTG TCT CTA
Lys Ala Leu Asn His Leu Lys Glu Asn Leu Lys Ile Ile His Arg Asp>

675    680    685    690    695    700    705    710    715    720
ATC AAA CCT TCC AAT ATT CTT CTG GAC AGA AGT GGA AAT ATT AAG CTC
TAG TTT GGA AGG TTA TAA GAA GAC CTG TCT TCA CCT TTA TAA TTC GAG
Ile Lys Pro Ser Asn Ile Leu Leu Asp Arg Ser Gly Asn Ile Lys Leu>

725    730    735    740    745    750    755    760    765    770
TGT GAC TTC GGC ATC AGT GGA CAG CTT GTG GAC TCT ATT GCC AAG ACA
ACA CTG AAG CCG TAG TCA CCT GTC GAA CAC CTG AGA TAA CGG TTC TGT
Cys Asp Phe Gly Ile Ser Gly Gln Leu Val Asp Ser Ile Ala Lys Thr>

   775    780    785    790    795    800    805    810    815
AGA GAT GCT GGC TGT AGG CCA TAC ATG GCA CCT GAA AGA ATA GAC CCA
TCT CTA CGA CCG ACA TCC GGT ATG TAC CGT GGA CTT TCT TAT CTG GGT
Arg Asp Ala Gly Cys Arg Pro Tyr Met Ala Pro Glu Arg Ile Asp Pro>

820    825    830    835    840    845    850    855    860    865
AGC GCA TCA CGA CAA GGA TAT GAT GTC CGC TCT GAT GTC TGG AGT TTG
TCG CGT AGT GCT GTT CCT ATA CTA CAG GCG AGA CTA CAG ACC TCA AAC
Ser Ala Ser Arg Gln Gly Tyr Asp Val Arg Ser Asp Val Trp Ser Leu>

   870    875    880    885    890    895    900    905    910
GGG ATC ACA TTG TAT GAG TTG GCC ACA GGC CGA TTT CCT TAT CCA AAG
CCC TAG TGT AAC ATA CTC AAC CGG TGT CCG GCT AAA GGA ATA GGT TTC
Gly Ile Thr Leu Tyr Glu Leu Ala Thr Gly Arg Phe Pro Tyr Pro Lys>

915    920    925    930    935    940    945    950    955    960
TGG AAT AGT GTA TTT GAT CAA CTA ACA CAA GTC GTG AAA GGA GAT CCT
ACC TTA TCA CAT AAA CTA GTT GAT TGT GTT CAG CAC TTT CCT CTA GGA
Trp Asn Ser Val Phe Asp Gln Leu Thr Gln Val Val Lys Gly Asp Pro>

965    970    975    980    985    990    995   1000   1005   1010
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FIG. 7 - CONT'D

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CCG CAG CTG AGT AAT TCT GAG GAA AGG GAA TTC TCC CCG AGT TTC ATC
GGC GTC GAC TCA TTA AGA CTC CTT TCC CTT AAG AGG GGC TCA AAG TAG
Pro Gln Leu Ser Asn Ser Glu Glu Arg Glu Phe Ser Pro Ser Phe Ile>

  1015   1020  1025   1030   1035  1040   1045   1050  1055
                *             *            *             *

AAC TTT GTC AAC TTG TGC CTT ACG AAG GAT GAA TCC AAA AGG CCA AAG
TTG AAA CAG TTG AAC ACG GAA TGC TTC CTA CTT AGG TTT TCC GGT TTC
Asn Phe Val Asn Leu Cys Leu Thr Lys Asp Glu Ser Lys Arg Pro Lys>

1060   1065  1070   1075   1080  1085   1090   1095  1100   1105
  *             *             *             *             *

TAT AAA GAG CTT CTG AAA CAT CCC TTT ATT TTG ATG TAT GAA GAA CGT
ATA TTT CTC GAA GAC TTT GTA GGG AAA TAA AAC TAC ATA CTT CTT GCA
Tyr Lys Glu Leu Leu Lys His Pro Phe Ile Leu Met Tyr Glu Glu Arg>

 1110  1115   1120   1125  1130   1135   1140  1145   1150
    *             *             *             *             *

GCC GTT GAG GTC GCA TGC TAT GTT TGT AAA ATC CTG GAT CAA ATG CCA
CGG CAA CTC CAG CGT ACG ATA CAA ACA TTT TAG GAC CTA GTT TAC GGT
Ala Val Glu Val Ala Cys Tyr Val Cys Lys Ile Leu Asp Gln Met Pro>

1155  1160   1165   1170  1175   1180   1185 1190  1195 1200
    *             *             *             *             *

GCT ACT CCC AGC TCT CCC ATG TAT GTC GAT TGATAT CGYTGCTACA
CGA TGA GGG TCG AGA GGG TAC ATA CAG CTA ACTATA GCRACGATGT
Ala Thr Pro Ser Ser Pro Met Tyr Val Asp> (SEQ ID NO:8)

 1205 1210  1215 1220  1225 1230  1235 1240  1245 1250  1255 1260
         *             *             *             *             *

TCAGACTCTA GAAAAAAGGG CTGAGAGGAA GCAAGACGTA AAGAATTTTC ATCCCGTATC
AGTCTGAGAT CTTTTTTCCC GACTCTCCTT CGTTCTGCAT TTCTTAAAAG TAGGGCATAG

 1265 1270  1275 1280  1285 1290  1295 1300  1305 1310  1315 1320
         *             *             *             *             *

ACAGTGTTTT TATTGCTCGC CCAGACACCA TGTGCAATAA GATTGGTGTT CGTTTCCATC
TGTCACAAAA ATAACGAGCG GGTCTGTGGT ACACGTTATT CTAACCACAA GCAAAGGTAG

 1325 1330  1335 1340  1345 1350  1355 1360  1365 1370  1375 1380
         *             *             *             *             *

ATGTCTGTAT ACTCCTGTCA CCTAGAACGT GCATCCTTGT AATACCTGAT TGATCACACA
TACAGACATA TGAGGACAGT GGATCTTGCA CGTAGGAACA TTATGGACTA ACTAGTGTGT

 1385 1390  1395 1400  1405 1410  1415 1420  1425 1430  1435 1440
         *             *             *             *             *

GTGTTAGTGC TGGTCAGAGA GACCTCATCC TGCTCTTTTG TGATGAACAT ATTCATGAAA
CACAATCACG ACCAGTCTCT CTGGAGTAGG ACGAGAAAAC ACTACTTGTA TAAGTACTTT

 1445 1450  1455 1460  1465 1470  1475 1480  1485 1490  1495 1500
         *             *             *             *             *

TGTGGAAGTC AGTACGATCA AGTTGTTGAC TGTGATTAGA TCACATCTTA AATTCATTTC
ACACCTTCAG TCATGCTAGT TCAACAACTG ACACTAATCT AGTGTAGAAT TTAAGTAAAG

 1505 1510  1515 1520  1525 1530  1535 1540  1545 1550  1555 1560
         *             *             *             *             *

TAGACTCAAA ACCTGGAGAT GCAGCTACTG GAATGGTGTT TTGTCAGACT TCCAAATCCT
ATCTGAGTTT TGGACCTCTA CGTCGATGAC CTTACCACAA AACAGTCTGA AGGTTTAGGA

 1565 1570  1575 1580  1585 1590  1595 1600  1605 1610  1615 1620
         *             *             *             *             *

GGAAGGACAC AGTGATGAAT GTACTATATC TGAACATAGA AACTCGGGCT TGAGTGAGAA
CCTTCCTGTG TCACTACTTA CATGATATAG ACTTGTATCT TTGAGCCCGA ACTCACTCTT
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FIG. 7 - CONT'D

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1625 1630  1635 1640  1645 1650  1655 1660  1665 1670  1675 1680
GAGCTTGCAC AGCCAACGAG ACACATTGCC TTCTGGAGCT GGGAGACAAA GGAGGAATTT
CTCGAACGTG TCGGTTGCTC TGTGTAACGG AAGACCTCGA CCCTCTGTTT CCTCCTTAAA

1685 1690  1695 1700  1705 1710  1715 1720  1725 1730  1735 1740
ACTTTCTTCA CCAAGTGCAA TAGATTACTG ATGTGATATT CTGTTGCTTT ACAGTTACAG
TGAAAGAAGT GGTTCACGTT ATCTAATGAC TACACTATAA GACAACGAAA TGTCAATGTC

1745 1750  1755 1760  1765 1770  1775 1780  1785 1790  1795 1800
TTGATGTTTG GGGATCGATG TGCTCAGCCA AATTTCCTGT TTGAAATATC ATGTTAAATT
AACTACAAAC CCCTAGCTAC ACGAGTCGGT TTAAAGGACA AACTTTATAG TACAATTTAA

1805 1810  1815 1820  1825 1830  1835 1840  1845 1850  1855 1860
AGAATGAATT TATCTTTACC AAAAACCATG TTGCGTTCAA AGAGGTGAAC ATTAAAATAT
TCTTACTTAA ATAGAAATGG TTTTTGGTAC AACGCAAGTT TCTCCACTTG TAATTTTATA

1865 1870  1875 1880  1885 1890  1895 1900  1905 1910  1915 1920
AGAGACAGGA CAGAATGTGT TCTTTTCTCC TCTACCAGTC CTATTTTTCA ATGGGAAGAC
TCTCTGTCCT GTCTTACACA AGAAAAGAGG AGATGGTCAG GATAAAAAGT TACCCTTCTG

1925 1930  1935 1940  1945 1950  1955 1960  1965 1970  1975 1980
TCAGGAGTCT GCCACTTGTC AAAGAAGGTG CTGATCCTAA GAATTTTTCA TTCTCAGAAT
AGTCCTCAGA CGGTGAACAG TTTCTTCCAC GACTAGGATT CTTAAAAAGT AAGAGTCTTA

1985 1990  1995 2000  2005 2010  2015 2020  2025 2030  2035 2040
TCGGTGTGCT GCCAACTTGA TGTTCCACCT GCCACAAACC ACCAGGACTG AAAGAAGAAA
AGCCACACGA CGGTTGAACT ACAAGGTGGA CGGTGTTTGG TGGTCCTGAC TTTCTTCTTT

2045 2050  2055 2060  2065 2070  2075 2080  2085 2090  2095 2100
ACAGTACAGA AGGCAAAGTT TACAGATGTT TTTAATTCTA GTATTTTATC TGGAACAACT
TGTCATGTCT TCCGTTTCAA ATGTCTACAA AAATTAAGAT CATAAAATAG ACCTTGTTGA

2105 2110  2115 2120  2125 2130  2135 2140  2145 2150  2155 2160
TGTAGCAGCT ATATATTTCC CCTTGGTCCC AAGCCTGATA CTTTAGCCAT CATAACTCAC
ACATCGTCGA TATATAAAGG GGAACCAGGG TTCGGACTAT GAAATCGGTA GTATTGAGTG

2165 2170  2175 2180  2185 2190  2195 2200  2205 2210  2215 2220
TAACAGGGAG AAGTAGCTAG TAGCAATGTG CCTTGATTGA TTAGATAAAG ATTTCTAGTA
ATTGTCCCTC TTCATCGATC ATCGTTACAC GGAACTAACT AATCTATTTC TAAAGATCAT

2225 2230  2235 2240  2245 2250  2255 2260  2265 2270  2275 2280
GGCAGCAAAA GACCAAATCT CAGTTGTTTG CTTCTTGCCA TCACTGGTCC AGGTCTTCAG
CCGTCGTTTT CTGGTTTAGA GTCAACAAAC GAAGAACGGT AGTGACCAGG TCCAGAAGTC

2285 2290  2295 2300  2305 2310  2315 2320  2325 2330  2335 2340
TTTCCGAATC TCTTTCCCTT CCCCTGTGGT CTATTGTCGC TATGTGACTT GCGCTTAATC
AAAGGCTTAG AGAAAGGGAA GGGGACACCA GATAACAGCG ATACACTGAA CGCGAATTAG

2345 2350  2355 2360  2365 2370  2375 2380  2385 2390  2395 2400
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FIG. 7 - CONT'D

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CAATATTTTG CCTTTTTTCT ATATCAAAAA ACCTTTACAG TTAGCAGGGA TGTTCCTTAC
GTTATAAAAC GGAAAAAAGA TATAGTTTTT TGGAAATGTC AATCGTCCCT ACAAGGAATG

2405 2410  2415 2420  2425 2430  2435 2440  2445 2450  2455 2460

CGAGGATTTT TAACCCCCAA TCTCTCATAA TCGCTAGTGT TTAAAAGGCT AAGAATAGTG
GCTCCTAAAA ATTGGGGGTT AGAGAGTATT AGCGATCACA AATTTTCCGA TTCTTATCAC

2465 2470  2475 2480  2485 2490  2495 2500  2505 2510  2515 2520

GGGCCCAACC GATGTGGTAG GTGATAAAGA GGCATCTTTT CTAGAGACAC ATTGGACCAG
CCCGGGTTGG CTACACCATC CACTATTTCT CCGTAGAAAA GATCTCTGTG TAACCTGGTC

2525 2530  2535 2540  2545 2550  2555 2560  2565 2570  2575 2580

ATGAGGATCC GAAACGGCAG CCTTTACGTT CATCACCTGC TAGAACCTCT CGTAGTCCAT
TACTCCTAGG CTTTGCCGTC GGAAATGCAA GTAGTGGACG ATCTTGGAGA GCATCAGGTA

2585 2590  2595 2600  2605 2610  2615 2620  2625 2630  2635 2640

CACCATTTCT TGGCATTGGA ATTCTACTGG AAAAAAATAC AAAAAGCAAA ACAAAACCCT
GTGGTAAAGA ACCGTAACCT TAAGATGACC TTTTTTTATG TTTTTCGTTT TGTTTTGGGA

2645 2650  2655 2660  2665 2670  2675 2680  2685 2690  2695 2700

CAGCACTGTT ACAAGAGGCC ATTTAAGTAT CTTGTGCTTC TTCACTTACC CATTAGCCAG
GTCGTGACAA TGTTCTCCGG TAAATTCATA GAACACGAAG AAGTGAATGG GTAATCGGTC

2705 2710  2715 2720  2725 2730  2735 2740  2745 2750  2755 2760

GTTCTCATTA GGTTTTGCTT GGGCCTCCCT GGCACTGAAC CTTAGGCTTT GTATGACAGT
CAAGAGTAAT CCAAAACGAA CCCGGAGGGA CCGTGACTTG GAATCCGAAA CATACTGTCA

2765 2770  2775 2780  2785 2790  2795 2800  2805 2810  2815 2820

GAAGCAGCAC TGTGAGTGGT TCAAGCACAC TGGAATATAA AACAGTCATG GCCTGAGATG
CTTCGTCGTG ACACTCACCA AGTTCGTGTG ACCTTATATT TTGTCAGTAC CGGACTCTAC

2825 2830  2835 2840  2845 2850  2855 2860  2865 2870  2875 2880

CAGGTGATGC CATTACAGAA CCAAATCGTG GCACGTATTG CTGTGTCTCC TCTCAGAGTG
GTCCACTACG GTAATGTCTT GGTTTAGCAC CGTGCATAAC GACACAGAGG AGAGTCTCAC

2885 2890  2895 2900  2905 2910  2915 2920  2925 2930  2935 2940

ACAGTCATAA ATACTGTCAA ACAATAAAGG GAGAATGGTG CTGTTTAAAG TCACATCCCT
TGTCAGTATT TATGACAGTT TGTTATTTCC CTCTTACCAC GACAAATTTC AGTGTAGGGA

2945 2950  2955 2960  2965 2970  2975 2980  2985 2990  2995 3000

GTAAATTGCA GAATTCAAAA GTGATTATCT CTTTGATCTA CTTGCCTCAT TTCCCTATCT
CATTTAACGT CTTAAGTTTT CACTAATAGA GAAACTAGAT GAACGGAGTA AAGGGATAGA

3005 3010  3015 3020  3025 3030  3035 3040  3045 3050  3055 3060

TCTCCCCCAC GGTATCCTAA ACTTTAGACT TCCCACTGTT CTGAAAGGAG ACATTGCTCT
AGAGGGGGTG CCATAGGATT TGAAATCTGA AGGGTGACAA GACTTTCCTC TGTAACGAGA

3065 3070  3075 3080  3085 3090  3095 3100  3105 3110  3115 3120

ATGTCTGCCT TCGACCACAG CAAGCCATCA TCCTCCATTG CTCCCGGGGA CTCAAGAGGA
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FIG. 7 - CONT'D

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TACAGACGGA AGCTGGTGTC GTTCGGTAGT AGGAGGTAAC GAGGGCCCCT GAGTTCTCCT

 3125 3130  3135 3140  3145 3150  3155 3160  3165 3170  3175 3180
           *         *         *         *         *         *
ATCTGTTTCT CTGCTGTCAA CTTCCCATCT GGCTCAGCAT AGGGTCACTT TGCCATTATG
TAGACAAAGA GACGACAGTT GAAGGGTAGA CCGAGTCGTA TCCCAGTGAA ACGGTAATAC

 3185 3190  3195 3200  3205 3210  3215 3220  3225 3230  3235 3240
           *         *         *         *         *         *
CAAATGGAGA TAAAAGCAAT TCTGGCTGTC CAGGAGCTAA TCTGACCGTT CTATTGTGTG
GTTTACCTCT ATTTTCGTTA AGACCGACAG GTCCTCGATT AGACTGGCAA GATAACACAC

 3245 3250  3255 3260  3265 3270  3275 3280  3285 3290  3295 3300
           *         *         *         *         *         *
GATGACCACA TAAGAAGGCA ATTTTAGTGT ATTAATCATA GATTATTATA AACTATAAAC
CTACTGGTGT ATTCTTCCGT TAAAATCACA TAATTAGTAT CTAATAATAT TTGATATTTG

 3305 3310  3315 3320  3325 3330  3335 3340  3345 3350  3355 3360
           *         *         *         *         *         *
TTAAGGGCAA GGAGTTTATT ACAATGTATC TTTATTAAAA CAAAAGGGTG TATAGTGTTC
AATTCCCGTT CCTCAAATAA TGTTACATAG AAATAATTTT GTTTTCCCAC ATATCACAAG

 3365 3370  3375 3380  3385 3390  3395 3400  3405 3410  3415 3420
           *         *         *         *         *         *
ACAAACTGTG AAAATAGTGT AAGAACTGTA CATTGTGAGC TCTGGTTATT TTTCTCTTGT
TGTTTGACAC TTTTATCACA TTCTTGACAT GTAACACTCG AGACCAATAA AAAGAGAACA

 3425 3430  3435 3440  3445 3450  3455 3460  3465 3470  3475 3480
           *         *         *         *         *         *
ACCATAGAAA AATGTATAAA AATTATCAAA AAGCTAATGT GCAGGGATAT TGCCTTATTT
TGGTATCTTT TTACATATTT TTAATAGTTT TTCGATTACA CGTCCCTATA ACGGAATAAA

 3485 3490  3495 3500  3505 3510  3515 3520  3525 3530  3535 3540
           *         *         *         *         *         *
GTCTGTAAAA AATGGAGCTC AGTAACATAA CTGCTTCTTG GAGCTTTGGA ATATTTTATC
CAGACATTTT TTACCTCGAG TCATTGTATT GACGAAGAAC CTCGAAACCT TATAAAATAG

 3545 3550
           *
CTGTATTCTT GTTT  (SEQ ID NO:7)
GACATAAGAA CAAA
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FIG. 8

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     5    10    15    20    25    30    35    40    45    50
          *     *     *     *     *     *     *     *
CTCCCAACA ATG GCG GCT CCG AGC CCG AGC GGC GGC GGC GGC TCC GGG GGC
GAGGGTTGT TAC CGC CGA GGC TCG GGC TCG CCG CCG CCG CCG AGG CCC CCG
          Met Ala Ala Pro Ser Pro Ser Gly Gly Gly Gly Ser Gly Gly>

    55    60    65    70    75    80    85    90    95
          *     *     *     *     *     *
GGC AGC GGC AGC GGC ACC CCC GGC CCC GTA GGG TCC CCG GCG CCA GGC
CCG TCG CCG TCG CCG TGG GGG CCG GGG CAT CCC AGG GGC CGC GGT CCG
Gly Ser Gly Ser Gly Thr Pro Gly Pro Val Gly Ser Pro Ala Pro Gly>

100   105   110   115   120   125   130   135   140   145
 *     *     *     *     *     *     *     *     *
CAC CCG GCC GTC AGC AGC ATG CAG GGT AAA CGC AAA GCA CTG AAG TTG
GTG GGC CGG CAG TCG TCG TAC GTC CCA TTT GCG TTT CGT GAC TTC AAC
His Pro Ala Val Ser Ser Met Gln Gly Lys Arg Lys Ala Leu Lys Leu>

 150    155    160   165    170    175   180    185    190   195
   *      *      *     *      *      *     *      *      *
AAT TTT GCA AAT CCA CCT TTC AAA TCT ACA GCA AGG TTT ACT CTG AAT
TTA AAA CGT TTA GGT GGA AAG TTT AGA TGT CGT TCC AAA TGA GAC TTA
Asn Phe Ala Asn Pro Pro Phe Lys Ser Thr Ala Arg Phe Thr Leu Asn>

    200   205   210   215   220   225   230   235   240
      *     *     *     *     *     *     *     *
CCC AAT CCT ACA GGA GTT CAA AAC CCA CAC ATA GAG AGA CTG AGA ACA
GGG TTA GGA TGT CCT CAA GTT TTG GGT GTG TAT CTC TCT GAC TCT TGT
Pro Asn Pro Thr Gly Val Gln Asn Pro His Ile Glu Arg Leu Arg Thr>

245    250   255    260   265   270    275   280   285    290
       *     *      *     *     *      *     *     *
CAC AGC ATT GAG TCA TCA GGA AAA CTG AAG ATC TCC CCT GAA CAA CAC
GTG TCG TAA CTC AGT AGT CCT TTT GAC TTC TAG AGG GGA CTT GTT GTG
His Ser Ile Glu Ser Ser Gly Lys Leu Lys Ile Ser Pro Glu Gln His>

   295   300    305   310   315   320   325   330    335
         *      *     *     *     *     *     *
TGG GAT TTC ACT GCA GAG GAC TTG AAA GAC CTT GGA GAA ATT GGA CGA
ACC CTA AAG TGA CGT CTC CTG AAC TTT CTG GAA CCT CTT TAA CCT GCT
Trp Asp Phe Thr Ala Glu Asp Leu Lys Asp Leu Gly Glu Ile Gly Arg>

340   345   350   355   360   365   370   375   380   385
 *     *     *     *     *     *     *     *     *
GGA GCT TAT GGT TCT GTC AAC AAA ATG GTC CAC AAA CCA AGT GGG CAA
CCT CGA ATA CCA AGA CAG TTG TTT TAC CAG GTG TTT GGT TCA CCC GTT
Gly Ala Tyr Gly Ser Val Asn Lys Met Val His Lys Pro Ser Gly Gln>

 390    395   400   405    410   415   420    425   430   435
   *      *     *     *      *     *     *      *     *
ATA ATG GCA GTT AAA AGA ATT CGG TCA ACA GTG GAT GAA AAA GAA CAA
TAT TAC CGT CAA TTT TCT TAA GCC AGT TGT CAC CTA CTT TTT CTT GTT
Ile Met Ala Val Lys Arg Ile Arg Ser Thr Val Asp Glu Lys Glu Gln>

    440   445   450   455   460   465   470   475   480
      *     *     *     *     *     *     *     *
AAA CAA CTT CTT ATG GAT TTG GAT GTA GTA ATG CGG AGT AGT GAT TGC
TTT GTT GAA GAA TAC CTA AAC CTA CAT CAT TAC GCC TCA TCA CTA ACG
Lys Gln Leu Leu Met Asp Leu Asp Val Val Met Arg Ser Ser Asp Cys>
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FIG. 8 - CONT'D

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485    490    495    500    505    510    515    520    525    530
       *      *      *      *      *      *      *      *
CCA TAC ATT GTT CAG TTT TAT GGT GCA CTC TTC AGA GAG GGT GAC TGT
GGT ATG TAA CAA GTC AAA ATA CCA CGT GAG AAG TCT CTC CCA CTG ACA
Pro Tyr Ile Val Gln Phe Tyr Gly Ala Leu Phe Arg Glu Gly Asp Cys>

  535    540    545    550    555    560    565    570    575
         *      *      *      *      *      *
TGG ATC TGT ATG GAA CTC ATG TCT ACC TCG TTT GAT AAG TTT TAC AAA
ACC TAG ACA TAC CTT GAG TAC AGA TGG AGC AAA CTA TTC AAA ATG TTT
Trp Ile Cys Met Glu Leu Met Ser Thr Ser Phe Asp Lys Phe Tyr Lys>

580    585    590    595    600    605    610    615    620    625
*      *      *      *      *      *      *      *
TAT GTA TAT AGT GTA TTA GAT GAT GTT ATT CCA GAA GAA ATT TTA GGC
ATA CAT ATA TCA CAT AAT CTA CTA CAA TAA GGT CTT CTT TAA AAT CCG
Tyr Val Tyr Ser Val Leu Asp Asp Val Ile Pro Glu Glu Ile Leu Gly>

630    635    640    645    650    655    660    665    670    675
*      *      *      *      *      *      *      *
AAA ATC ACT TTA GCA ACT GTG AAA GCA CTA AAC CAC TTA AAA GAA AAC
TTT TAG TGA AAT CGT TGA CAC TTT CGT GAT TTG GTG AAT TTT CTT TTG
Lys Ile Thr Leu Ala Thr Val Lys Ala Leu Asn His Leu Lys Glu Asn>

  680    685    690    695    700    705    710    715    720
         *      *      *      *      *      *
TTG AAA ATT ATT CAC AGA GAT ATC AAA CCT TCC AAT ATT CTT CTG GAC
AAC TTT TAA TAA GTG TCT CTA TAG TTT GGA AGG TTA TAA GAA GAC CTG
Leu Lys Ile Ile His Arg Asp Ile Lys Pro Ser Asn Ile Leu Leu Asp>

725    730    735    740    745    750    755    760    765    770
       *      *      *      *      *      *      *      *
AGA AGT GGA AAT ATT AAG CTC TGT GAC TTC GGC ATC AGT GGA CAG CTT
TCT TCA CCT TTA TAA TTC GAG ACA CTG AAG CCG TAG TCA CCT GTC GAA
Arg Ser Gly Asn Ile Lys Leu Cys Asp Phe Gly Ile Ser Gly Gln Leu>

  775    780    785    790    795    800    805    810    815
         *      *      *      *      *      *
GTG GAC TCT ATT GCC AAG ACA AGA GAT GCT GGC TGT AGG CCA TAC ATG
CAC CTG AGA TAA CGG TTC TGT TCT CTA CGA CCG ACA TCC GGT ATG TAC
Val Asp Ser Ile Ala Lys Thr Arg Asp Ala Gly Cys Arg Pro Tyr Met>

820    825    830    835    840    845    850    855    860    865
*      *      *      *      *      *      *      *
GCA CCT GAA AGA ATA GAC CCA AGC GCA TCA CGA CAA GGA TAT GAT GTC
CGT GGA CTT TCT TAT CTG GGT TCG CGT AGT GCT GTT CCT ATA CTA CAG
Ala Pro Glu Arg Ile Asp Pro Ser Ala Ser Arg Gln Gly Tyr Asp Val>

870    875    880    885    890    895    900    905    910    915
*      *      *      *      *      *      *      *
CGC TCT GAT GTC TGG AGT TTG GGG ATC ACA TTG TAT GAG TTG GCC ACA
GCG AGA CTA CAG ACC TCA AAC CCC TAG TGT AAC ATA CTC AAC CGG TGT
Arg Ser Asp Val Trp Ser Leu Gly Ile Thr Leu Tyr Glu Leu Ala Thr>

  920    925    930    935    940    945    950    955    960
         *      *      *      *      *      *
GGC CGA TTT CCT TAT CCA AAG TGG AAT AGT GTA TTT GAT CAA CTA ACA
CCG GCT AAA GGA ATA GGT TTC ACC TTA TCA CAT AAA CTA GTT GAT TGT
Gly Arg Phe Pro Tyr Pro Lys Trp Asn Ser Val Phe Asp Gln Leu Thr>

965    970    975    980    985    990    995   1000  1005   1010
       *      *      *      *      *      *      *
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FIG. 8 - CONT'D

```
CAA GTC GTG AAA GGA GAT CCT CCG CAG CTG AGT AAT TCT GAG GAA AGG
GTT CAG CAC TTT CCT CTA GGA GGC GTC GAC TCA TTA AGA CTC CTT TCC
Gln Val Val Lys Gly Asp Pro Pro Gln Leu Ser Asn Ser Glu Glu Arg>

 1015  1020   1025   1030  1035   1040   1045  1050   1055
          *             *             *             *

GAA TTC TCC CCG AGT TTC ATC AAC TTT GTC AAC TTG TGC CTT ACG AAG
CTT AAG AGG GGC TCA AAG TAG TTG AAA CAG TTG AAC ACG GAA TGC TTC
Glu Phe Ser Pro Ser Phe Ile Asn Phe Val Asn Leu Cys Leu Thr Lys>

1060  1065   1070   1075  1080   1085   1090  1095   1100   1105
  *             *             *             *             *

GAT GAA TCC AAA AGG CCA AAG TAT AAA GAG CTT CTG AAA CAT CCC TTT
CTA CTT AGG TTT TCC GGT TTC ATA TTT CTC GAA GAC TTT GTA GGG AAA
Asp Glu Ser Lys Arg Pro Lys Tyr Lys Glu Leu Leu Lys His Pro Phe>

 1110   1115   1120  1125   1130   1135  1140   1145   1150  1155
   *             *             *             *             *

ATT TTG ATG TAT GAA GAA CGT GCC GTT GAG GTC GCA TGC TAT GTT TGT
TAA AAC TAC ATA CTT CTT GCA CGG CAA CTC CAG CGT ACG ATA CAA ACA
Ile Leu Met Tyr Glu Glu Arg Ala Val Glu Val Ala Cys Tyr Val Cys>

  1160   1165  1170   1175   1180  1185   1190   1195  1200
    *             *             *             *             *

AAA ATC CTG GAT CAA ATG CCA GCT ACT CCC AGC TCT CCC ATG TAT GTC
TTT TAG GAC CTA GTT TAC GGT CGA TGA GGG TCG AGA GGG TAC ATA CAG
Lys Ile Leu Asp Gln Met Pro Ala Thr Pro Ser Ser Pro Met Tyr Val>

1205  1210  1215 1220  1225 1230  1235 1240  1245 1250  1255 1260
          *             *             *             *             *

GAT TGAT ATCGCTGCTA CATCAGACTC TAGAAAAAAG GGCTGAGAGG AAGCAAGACG
CTA ACTA TAGCGACGAT GTAGTCTGAG ATCTTTTTTC CCGACTCTCC TTCGTTCTGC
Asp>  (SEQ ID NO:10)

 1265 1270  1275 1280  1285 1290  1295 1300  1305 1310  1315 1320
          *             *             *             *             *

TAAAGAATTT TCATCCCGTA TCACAGTGTT TTTATTGCTC GCCCAGACAC CATGTGCAAT
ATTTCTTAAA AGTAGGGCAT AGTGTCACAA AAATAACGAG CGGGTCTGTG GTACACGTTA

 1325 1330  1335 1340  1345 1350  1355 1360  1365 1370  1375 1380
          *             *             *             *             *

AAGATTGGTG TTCGTTTCCA TCATGTCTGT ATACTCCTGT CACCTAGAAC GTGCATCCTT
TTCTAACCAC AAGCAAAGGT AGTACAGACA TATGAGGACA GTGGATCTTG CACGTAGGAA

 1385 1390  1395 1400  1405 1410  1415 1420  1425 1430  1435 1440
          *             *             *             *             *

GTAATACCTG ATTGATCACA CAGTGTTAGT GCTGGTCAGA GAGACCTCAT CCTGCTCTTT
CATTATGGAC TAACTAGTGT GTCACAATCA CGACCAGTCT CTCTGGAGTA GGACGAGAAA

 1445 1450  1455 1460  1465 1470  1475 1480  1485 1490  1495 1500
          *             *             *             *             *

TGTGATGAAC ATATTCATGA AATGTGGAAG TCAGTACGAT CAAGTTGTTG ACTGTGATTA
ACACTACTTG TATAAGTACT TTACACCTTC AGTCATGCTA GTTCAACAAC TGACACTAAT

 1505 1510  1515 1520  1525 1530  1535 1540  1545 1550  1555 1560
          *             *             *             *             *

GATCACATCT TAAATTCATT TCTAGACTCA AAACCTGGAG ATGCAGCTAC TGGAATGGTG
CTAGTGTAGA ATTTAAGTAA AGATCTGAGT TTTGGACCTC TACGTCGATG ACCTTACCAC

 1565 1570  1575 1580  1585 1590  1595 1600  1605 1610  1615 1620
          *             *             *             *             *

TTTTGTCAGA CTTCCAAATC CTGGAAGGAC ACAGTGATGA ATGTACTATA TCTGAACATA
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FIG. 8 - CONT'D

```
AAAACAGTCT GAAGGTTTAG GACCTTCCTG TGTCACTACT TACATGATAT AGACTTGTAT

 1625 1630  1635 1640  1645 1650  1655 1660  1665 1670  1675 1680
          *         *         *         *         *         *
GAAACTCGGG CTTGAGTGAG AAGAGCTTGC ACAGCCAACG AGACACATTG CCTTCTGGAG
CTTTGAGCCC GAACTCACTC TTCTCGAACG TGTCGGTTGC TCTGTGTAAC GGAAGACCTC

 1685 1690  1695 1700  1705 1710  1715 1720  1725 1730  1735 1740
          *         *         *         *         *         *
CTGGGAGACA AAGGAGGAAT TTACTTTCTT CACCAAGTGC AATAGATTAC TGATGTGATA
GACCCTCTGT TTCCTCCTTA AATGAAAGAA GTGGTTCACG TTATCTAATG ACTACACTAT

 1745 1750  1755 1760  1765 1770  1775 1780  1785 1790  1795 1800
          *         *         *         *         *         *
TTCTGTTGCT TTACAGTTAC AGTTGATGTT TGGGGATCGA TGTGCTCAGC CAAATTTCCT
AAGACAACGA AATGTCAATG TCAACTACAA ACCCCTAGCT ACACGAGTCG GTTTAAAGGA

 1805 1810  1815 1820  1825 1830  1835 1840  1845 1850  1855 1860
          *         *         *         *         *         *
GTTTGAAATA TCATGTTAAA TTAGAATGAA TTTATCTTTA CCAAAAACCA TGTTGCGTTC
CAAACTTTAT AGTACAATTT AATCTTACTT AAATAGAAAT GGTTTTTGGT ACAACGCAAG

 1865 1870  1875 1880  1885 1890  1895 1900  1905 1910  1915 1920
          *         *         *         *         *         *
AAAGAGGTGA ACATTAAAAT ATAGAGACAG GACAGAATGT GTTCTTTTCT CCTCTACCAG
TTTCTCCACT TGTAATTTTA TATCTCTGTC CTGTCTTACA CAAGAAAAGA GGAGATGGTC

 1925 1930  1935 1940  1945 1950  1955 1960  1965 1970  1975 1980
          *         *         *         *         *         *
TCCTATTTTT CAATGGGAAG ACTCAGGAGT CTGCCACTTG TCAAAGAAGG TGCTGATCCT
AGGATAAAAA GTTACCCTTC TGAGTCCTCA GACGGTGAAC AGTTTCTTCC ACGACTAGGA

 1985 1990  1995 2000  2005 2010  2015 2020  2025 2030  2035 2040
          *         *         *         *         *         *
AAGAATTTTT CATTCTCAGA ATTCGGTGTG CTGCCAACTT GATGTTCCAC CTGCCACAAA
TTCTTAAAAA GTAAGAGTCT TAAGCCACAC GACGGTTGAA CTACAAGGTG GACGGTGTTT

 2045 2050  2055 2060  2065 2070  2075 2080  2085 2090  2095 2100
          *         *         *         *         *         *
CCACCAGGAC TGAAAGAAGA AAACAGTACA GAAGGCAAAG TTTACAGATG TTTTTAATTC
GGTGGTCCTG ACTTTCTTCT TTTGTCATGT CTTCCGTTTC AAATGTCTAC AAAAATTAAG

 2105 2110  2115 2120  2125 2130  2135 2140  2145 2150  2155 2160
          *         *         *         *         *         *
TAGTATTTTA TCTGGAACAA CTTGTAGCAG CTATATATTT CCCCTTGGTC CCAAGCCTGA
ATCATAAAAT AGACCTTGTT GAACATCGTC GATATATAAA GGGGAACCAG GGTTCGGACT

 2165 2170  2175 2180  2185 2190  2195 2200  2205 2210  2215 2220
          *         *         *         *         *         *
TACTTTAGCC ATCATAACTC ACTAACAGGG AGAAGTAGCT AGTAGCAATG TGCCTTGATT
ATGAAATCGG TAGTATTGAG TGATTGTCCC TCTTCATCGA TCATCGTTAC ACGGAACTAA

 2225 2230  2235 2240  2245 2250  2255 2260  2265 2270  2275 2280
          *         *         *         *         *         *
GATTAGATAA AGATTTCTAG TAGGCAGCAA AAGACCAAAT CTCAGTTGTT TGCTTCTTGC
CTAATCTATT TCTAAAGATC ATCCGTCGTT TTCTGGTTTA GAGTCAACAA ACGAAGAACG

 2285 2290  2295 2300  2305 2310  2315 2320  2325 2330  2335 2340
          *         *         *         *         *         *
CATCACTGGT CCAGGTCTTC AGTTTCCGAA TCTCTTTCCC TTCCCCTGTG GTCTATTGTC
GTAGTGACCA GGTCCAGAAG TCAAAGGCTT AGAGAAAGGG AAGGGGACAC CAGATAACAG
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FIG. 8 - CONT'D

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2345 2350  2355 2360  2365 2370  2375 2380  2385 2390  2395 2400
GCTATGTGAC TTGCGCTTAA TCCAATATTT TGCCTTTTTT CTATATCAAA AAACCTTTAC
CGATACACTG AACGCGAATT AGGTTATAAA ACGGAAAAAA GATATAGTTT TTTGGAAATG

2405 2410  2415 2420  2425 2430  2435 2440  2445 2450  2455 2460
AGTTAGCAGG GATGTTCCTT ACCGAGGATT TTTAACCCCC AATCTCTCAT AATCGCTAGT
TCAATCGTCC CTACAAGGAA TGGCTCCTAA AAATTGGGGG TTAGAGAGTA TTAGCGATCA

2465 2470  2475 2480  2485 2490  2495 2500  2505 2510  2515 2520
GTTTAAAAGG CTAAGAATAG TGGGGCCCAA CCGATGTGGT AGGTGATAAA GAGGCATCTT
CAAATTTTCC GATTCTTATC ACCCCGGGTT GGCTACACCA TCCACTATTT CTCCGTAGAA

2525 2530  2535 2540  2545 2550  2555 2560  2565 2570  2575 2580
TTCTAGAGAC ACATTGGACC AGATGAGGAT CCGAAACGGC AGCCTTTACG TTCATCACCT
AAGATCTCTG TGTAACCTGG TCTACTCCTA GGCTTTGCCG TCGGAAATGC AAGTAGTGGA

2585 2590  2595 2600  2605 2610  2615 2620  2625 2630  2635 2640
GCTAGAACCT CTCGTAGTCC ATCACCATTT CTTGGCATTG GAATTCTACT GGAAAAAAAT
CGATCTTGGA GAGCATCAGG TAGTGGTAAA GAACCGTAAC CTTAAGATGA CCTTTTTTTA

2645 2650  2655 2660  2665 2670  2675 2680  2685 2690  2695 2700
ACAAAAAGCA AAACAAAACC CTCAGCACTG TTACAAGAGG CCATTTAAGT ATCTTGTGCT
TGTTTTTCGT TTTGTTTTGG GAGTCGTGAC AATGTTCTCC GGTAAATTCA TAGAACACGA

2705 2710  2715 2720  2725 2730  2735 2740  2745 2750  2755 2760
TCTTCACTTA CCCATTAGCC AGGTTCTCAT TAGGTTTTGC TTGGGCCTCC CTGGCACTGA
AGAAGTGAAT GGGTAATCGG TCCAAGAGTA ATCCAAAACG AACCCGGAGG GACCGTGACT

2765 2770  2775 2780  2785 2790  2795 2800  2805 2810  2815 2820
ACCTTAGGCT TTGTATGACA GTGAAGCAGC ACTGTGAGTG GTTCAAGCAC ACTGGAATAT
TGGAATCCGA AACATACTGT CACTTCGTCG TGACACTCAC CAAGTTCGTG TGACCTTATA

2825 2830  2835 2840  2845 2850  2855 2860  2865 2870  2875 2880
AAAACAGTCA TGGCCTGAGA TGCAGGTGAT GCCATTACAG AACCAAATCG TGGCACGTAT
TTTTGTCAGT ACCGGACTCT ACGTCCACTA CGGTAATGTC TTGGTTTAGC ACCGTGCATA

2885 2890  2895 2900  2905 2910  2915 2920  2925 2930  2935 2940
TGCTGTGTCT CCTCTCAGAG TGACAGTCAT AAATACTGTC AAACAATAAA GGGAGAATGG
ACGACACAGA GGAGAGTCTC ACTGTCAGTA TTTATGACAG TTTGTTATTT CCCTCTTACC

2945 2950  2955 2960  2965 2970  2975 2980  2985 2990  2995 3000
TGCTGTTTAA AGTCACATCC CTGTAAATTG CAGAATTCAA AAGTGATTAT CTCTTTGATC
ACGACAAATT TCAGTGTAGG GACATTTAAC GTCTTAAGTT TTCACTAATA GAGAAACTAG

3005 3010  3015 3020  3025 3030  3035 3040  3045 3050  3055 3060
TACTTGCCTC ATTTCCCTAT CTTCTCCCCC ACGGTATCCT AAACTTTAGA CTTCCCACTG
ATGAACGGAG TAAAGGGATA GAAGAGGGGG TGCCATAGGA TTTGAAATCT GAAGGGTGAC

3065 3070  3075 3080  3085 3090  3095 3100  3105 3110  3115 3120
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FIG. 8 - CONT'D

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TTCTGAAAGG AGACATTGCT CTATGTCTGC CTTCGACCAC AGCAAGCCAT CATCCTCCAT
AAGACTTTCC TCTGTAACGA GATACAGACG GAAGCTGGTG TCGTTCGGTA GTAGGAGGTA

 3125 3130  3135 3140  3145 3150  3155 3160  3165 3170  3175 3180
        *         *         *         *         *         *

TGCTCCCGGG GACTCAAGAG GAATCTGTTT CTCTGCTGTC AACTTCCCAT CTGGCTCAGC
ACGAGGGCCC CTGAGTTCTC CTTAGACAAA GAGACGACAG TTGAAGGGTA GACCGAGTCG

 3185 3190  3195 3200  3205 3210  3215 3220  3225 3230  3235 3240
        *         *         *         *         *         *

ATAGGGTCAC TTTGCCATTA TGCAAATGGA GATAAAAGCA ATTCTGGCTG TCCAGGAGCT
TATCCCAGTG AAACGGTAAT ACGTTTACCT CTATTTTCGT TAAGACCGAC AGGTCCTCGA

 3245 3250  3255 3260  3265 3270  3275 3280  3285 3290  3295 3300
        *         *         *         *         *         *

AATCTGACCG TTCTATTGTG TGGATGACCA CATAAGAAGG CAATTTTAGT GTATTAATCA
TTAGACTGGC AAGATAACAC ACCTACTGGT GTATTCTTCC GTTAAAATCA CATAATTAGT

 3305 3310  3315 3320  3325 3330  3335 3340  3345 3350  3355 3360
        *         *         *         *         *         *

TAGATTATTA TAAACTATAA ACTTAAGGGC AAGGAGTTTA TTACAATGTA TCTTTATTAA
ATCTAATAAT ATTTGATATT TGAATTCCCG TTCCTCAAAT AATGTTACAT AGAAATAATT

 3365 3370  3375 3380  3385 3390  3395 3400  3405 3410  3415 3420
        *         *         *         *         *         *

AACAAAAGGG TGTATAGTGT TCACAAACTG TGAAAATAGT GTAAGAACTG TACATTGTGA
TTGTTTTCCC ACATATCACA AGTGTTTGAC ACTTTTATCA CATTCTTGAC ATGTAACACT

 3425 3430  3435 3440  3445 3450  3455 3460  3465 3470  3475 3480
        *         *         *         *         *         *

GCTCTGGTTA TTTTTCTCTT GTACCATAGA AAAATGTATA AAAATTATCA AAAAGCTAAT
CGAGACCAAT AAAAAGAGAA CATGGTATCT TTTTACATAT TTTTAATAGT TTTTCGATTA

 3485 3490  3495 3500  3505 3510  3515 3520  3525 3530  3535 3540
        *         *         *         *         *         *

GTGCAGGGAT ATTGCCTTAT TTGTCTGTAA AAAATGGAGC TCAGTAACAT AACTGCTTCT
CACGTCCCTA TAACGGAATA AACAGACATT TTTTACCTCG AGTCATTGTA TTGACGAAGA

 3545 3550  3555 3560  3565 3570  3575
        *         *         *

TGGAGCTTTG GAATATTTTA TCCTGTATTC TTGTTT  (SEQ ID NO:9)
ACCTCGAAAC CTTATAAAAT AGGACATAAG AACAAA
```

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/01078

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :C07K 14/435, 16/00; C07H 21/04; C12Q 1/68; G01N 33/53
US CL : 536/23.2; 530/387.1; 530/350; 435/6; 436/7.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 536/23.2; 530/387.1; 530/350; 435/6; 436/7.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, DIALOG, MEDLINE, WPI, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO, A, 94/24159 (NATIONAL JEWISH CENTER FOR IMMUNOLOGY AND RESPIRATORY MEDICINE) 27 October 1994, see pages 8, 16, 18, 21, 22, 28, 30, 38, 59, 60.	1, 22-37
Y	Journal Of Biological Chemistry, Volume 267, No. 36, issued 25 December 1992, Seger et al, "Human T-cell Mitogen-Activated Protein Kinases Are Related To Yeast Signal Transduction Kinases", pages 25628-25631, especially page 25630.	29
Y	Molecular And Cellular Biology, Volume 13, No. 8, issued August 1993, Wu et al, "Identification and Characterization of a New Mammalian Mitogen-Activated Protein Kinase Kinase, MKK2", pages 4539-4548, especically pages 4542 and 4543.	24, 28-32

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be part of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search	Date of mailing of the international search report
08 MAY 1996	24 MAY 1996
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer JOHN M. LUCAS
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/01078

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IPC(6) :C07K 14/435, 16/00; C07H 21/04; C12Q 1/68; G01N 33/53
US CL : 536/23.2; 530/387.1; 530/350; 435/6; 436/7.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 536/23.2; 530/387.1; 530/350; 435/6; 436/7.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, DIALOG, MEDLINE, WPI, BIOSIS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	Journal Of Biological Chemistry, Volume 267, No. 36, issued 25 December 1992, Seger et al, "Human T-cell Mitogen-Activated Protein Kinases Are Related To Yeast Signal Transduction Kinases", pages 25628-25631, especially page 25630.	29
Y	Molecular And Cellular Biology, Volume 13, No. 8, issued August 1993, Wu et al, "Identification and Characterization of a New Mammalian Mitogen-Activated Protein Kinase Kinase, MKK2", pages 4539-4548, especically pages 4542 and 4543.	24, 28-32

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"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&"	document member of the same patent family
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 08 MAY 1996	Date of mailing of the international search report 24 MAY 1996
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